TV SERVICING

PRACTICAL INFORMATION ON

- TV TROUBLE SHOOTING
- TV TUNER ALIGNMENT
- TV CIRCUIT ANALYSIS

RADIO CORPORATION of AMERICA
TUBE DEPARTMENT
HARRISON, N. J.
TV SERVICING

—A compilation of articles on TV servicing written by two of RCA’s experts in the fields of TV servicing and test equipment—John R. Meagher, Television Specialist, and Art Liebscher, RCA Test Equipment Specialist.

"TV Servicing" has been prepared to take care of numerous requests for copies of the articles by Mr. Meagher which appeared in "RCA Service News" under the general titles of "Television Service" and "Television Antennas and Transmission Lines". His recent articles on "Horizontal Pulling" and a previously unpublished article on "Audible Hum and Buzz" have also been included to increase the usefulness of this publication.

A new article, "Television Tuner Alignment," by Art Liebscher is a thorough, practical guide to tuner alignment. It will be particularly welcomed by those servicemen who have shied away from this phase of TV servicing—the article disproves the popular misconception that television tuners are complicated devices.

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TELEVISION SERVICE

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PART I
USING THE TEST PATTERN

When something goes wrong in a television receiver, it generally shows up as a definite symptom in the picture. In no other type of electronic equipment are the troubles and symptoms so clearly displayed before our eyes.

If we learn to recognize these visible symptoms, we can quickly localize the trouble to a particular portion of the set. Even the complete absence of picture and raster tells us to suspect certain definite parts.

For those who hope to become expert in television service, it will pay to study, observe, and learn how to analyze symptoms in the television picture.

There are several text books that cover television principles, the action of television circuits, and the effects of some interference conditions, but there is practically no information that correlates specific troubles with the visible symptoms.

So in this series of articles, we will concentrate on diagnosing and localizing troubles by analyzing their effects on the picture.

However, in order to build a foundation for subsequent articles, it is logical and necessary to start with a discussion on how to interpret and use the television test pattern. This includes much practical service information.

Typical test patterns

There is no standard test pattern in general use. The nearest thing to a standard is the RCA "Indian head" monoscope, which is used by a number of TV stations. RMA has proposed a standard test pattern chart, but for various reasons it has not been adopted by TV stations for air use.

Many TV stations have designed their own test patterns, which, although differing in appearance, are all intended to facilitate adjustments and checks in both the transmitting equipment and the receivers.

Two typical test patterns, the NBC, and the RCA Indian head, are shown in Figures 1 and 2. The various elements are named in Figure 1, and these names will be referred to in the following discussion.

Size and linearity

The controls for width, horizontal drive, and horizontal linearity, and the controls for height and vertical linearity should be adjusted so that:

1. The circles in the test pattern are as round as possible, and
2. The test pattern is slightly larger than the mask appearing in front of the kinescope.

If linearity is not correct, the circles will be flattened or egg-shaped.

In judging vertical linearity, it helps if you lay your head on your shoulder and look sideways at the picture. This makes vertical non-linearity more apparent.

Many TV owners are extremely fussy about having the circles exactly round. Some of them check the circles by holding a small plate in front of the screen, and others measure the wedges to see if they are equal lengths. In some TV areas, this makes life extremely difficult for the television technicians, because it is an unfortunate fact that some stations do not transmit good linearity.

Also, the linearity may be different from one camera to another. In one particular city, if the receiver is adjusted so the test-pattern circle is round on the first station, the second station will be egg-shaped vertically, and the third station will be egg-shaped horizontally.

In the latter case, it is sometimes necessary for the technician to adjust the receiver for the best compromise linearity on all stations in the area. But it is preferable to select the station that is most likely to have correct linearity, and adjust the receiver on this station, because in time the other stations will correct their nonlinearity.

Frequently, it is necessary to install and adjust TV receivers at night or when there are regular programs, but no test patterns on the air. In such cases, it is possible to use a "bar generator" which produces a number of vertical and horizontal bars on the picture. These bars are "synced" by the sync pulses so that the bars remain stationary on the picture. The set is then adjusted for equal spacing between the bars.

A very useful hint for checking and adjusting vertical linearity when there are only programs and no test patterns on the air, is to turn the vertical-hold control so the picture keeps rolling slowly from top to bottom. If the vertical linearity is good, the black vertical-blanking bar will remain the same thickness in all positions from the top to the bottom. This is shown in Figure 3. There is no similar easy way to check horizontal linearity.

In a few test patterns, all circles are intentionally omitted: regularly spaced horizontal and vertical lines are used to check and adjust linearity, as shown in Figure 4. This design of test pattern is the answer to the technician's prayers, because it avoids the trouble of the fussy customer who insists that the circles be exactly round, yet it provides a satisfactory means for adjusting linearity within reasonable limits.

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caused by incorrect adjustment of the receiver, or by failure or change in value of components, in the deflection circuits of the receiver. The question of whether the station or the receiver is at fault can be determined by experience with a number of different receivers, or by the use of a bar generator.

Most TV set owners complain if the picture does not completely fill the mask, but they do not complain if a small portion of the picture is hidden behind the mask.

3. There may be some drift in the picture size or centering during the first hour of operation.

For these and other reasons, experience has taught that it is a practical necessity to make the picture extend slightly beyond the mask.

The test pattern should be designed with this in mind. For example, if the pattern has small circles or other information too close to the corners, it may cause unnecessary headaches for the technician, because when the picture is made larger than the mask, the designs in the corner may be partly hidden. Some TV owners want to know why.

Figure 3. Checking Vertical Linearity with Vertical Blocking Bar.

**Centering**

The two arcs of circles in the NBC pattern, Figure 1, are an aid in adjusting horizontal centering. The main black circle is used in adjusting vertical centering.

**Focus**

The television signal controls the intensity of the electron beam in the kinescope. This beam produces a fluorescent spot of light on the inner face of the kinescope. It is this spot that "paints" the picture.

For good definition or resolution, or ability to make very small details evident and distinct in the picture, the spot must be small and round. It should be small enough so that the horizontal line structure can be seen distinctly, and it should be round in order to get the best definition from top to bottom and from left to right.

If the spot is slightly elliptical or oval shaped, instead of round, it may be handled by adjusting the focus control, as described below.

The vertical and horizontal wedges are used in adjusting focus; they provide a check on the shape of the kinescope spot, as follows:

Closely examine the separate lines toward the narrow end of the vertical wedge, and adjust the focus control so these lines are in best focus, or sharpest.

Then look at the lines toward the narrow end of the horizontal wedge, and see if a slight readjustment of focus improves the focus on these lines.

If best focus on both the vertical and horizontal wedges is obtained at the same setting of the focus control, it may be assumed that the spot is oval.

If the setting for best focus is slightly different for the two wedges, it indicates that the spot is oval. In this case it is generally preferable to adjust the control for best focus on the vertical wedge.

In most test patterns, the narrow ends of the wedges are intentionally placed near the center of the test pattern. By focusing here, it ensures that the picture will be in best focus at the center, which is desirable.

Some test patterns, such as Figure 1, provide additional wedges in the corners to show whether the focus is good on the sides and top and bottom, compared with the center.

If focus is not reasonably uniform over the entire picture, it may indicate need for repositioning of the iron-trap magnet, or the focusing coil and focusing control.

If the test pattern does not have wedges in the corners, the horizontal scanning lines of the receiver can be observed to check focus over the entire screen.

When focus must be adjusted on a program, without the help of a test pattern, it is generally satisfactory to adjust for the finest scanning lines near the center of the picture.

Figure 4. Horizontal and Vertical Lines instead of Circles for Linearity Check.

**Contrast and brightness**

Almost all test patterns include some form of shading blocks to assist in correctly adjusting contrast and brightness.

The shading blocks have at least five shades, black, dark grey, medium grey, light grey, and white. The contrast and brightness should be adjusted so that each shade is distinguishable. With contrast too high, the darker greys become black, and with contrast too low, the lighter greys become washed out.

If brightness and contrast are set too high, the definition will suffer, owing to "blooming" of the kinescope spot. When the spot is too bright, it grows larger, and best definition depends on a small spot.

Instead of shading blocks, some test patterns have a section of light grey background with white lettering, and a section of darker grey background with black lettering. This serves the same purpose on the shading blocks, and is more foolproof, because few persons are aware of the significance of the shading blocks.

Many test patterns are designed with a grey background to secure an average modulation of 50%. This reduces the need for readjusting brightness and contrast when the station switches from the test pattern to an average program. It is a desirable feature (except when photographing a pattern).

**Interlacing**

The horizontal wedges show lack of interlacing by a moire pattern, or wavy effect, toward the narrow end of the horizontal wedges. A moire pattern is somewhat similar to the effect that is seen when looking through two pieces of window screening, or at a piece of satin.

The appearance of poor interlacing can usually be duplicated by turning the vertical-hold control slowly until the picture is just beginning to move down. At this point the moire effect will be seen on the horizontal wedges. Also the horizontal scanning lines of interlacing, will lay over each other, or "pair". This pairing can be observed by the increased dark space between the horizontal scanning lines, particularly near the top of the picture.

Lack of correct interlace also produces a jagged or saw-tooth effect on diagonal lines and on the circles. The Indian-head test pattern has diagonal lines for this reason.

Some test patterns have closely-spaced concentric circles which show the moire effect if interlacing is poor.

On some TV stations, all receivers may show evidence of poor interlace on the horizontal wedges. In this a second test pattern may need to worry about the receivers. It is likely that there will be no evidence of poor interlacing when the station switches to a program. In looking at a test pattern on a kinescope, there may be an optical illusion of vertical jitters. By looking at a small part of the scanning lines through a ¼-inch hole in a piece of thin cardboard held against the face of the kinescope, it is possible to determine whether the jitter is an optical effect, or real.
PART II

Low-frequency phase shift

The general subject of phase shift in relation to the diagnosis and repair of TV receivers will be covered in a subsequent article. At present, we will give a brief outline of the trouble, and describe some of the symptoms as seen on the test pattern and in the picture.

Any horizontal line in the test pattern may be regarded as representing a half-cycle of a relatively low-frequency square wave. For example, on a 10-inch receiver, a half-cycle of one-megacycle is approximately 1/4-inch long, and a half-cycle of 100 kc is 1/10-inch long. See Figure 5.

A square wave is composed of a fundamental and numerous harmonics of different amplitudes. For good reproduction all of these components must be amplified equally and have the same time delay in passing through the receiver. Otherwise, the signal arriving at the kinescope will be a distorted square wave: It may have a dip before or behind (leading and trailing reversals), it may trail off very gradually (X-ray effect), it may have a dip before or after (X-ray effect), or it may be very gradually instead of sharply.

This trailing-off makes a long smear after horizontal lines. Incidentally, this accounts for the "X-ray" effect, where a long horizontal mold- ing or shelf can be "seen" right through a person standing in front of it.

The effect of low-frequency phase shift is more evident in the picture if the horizontal lines are fairly thick. The thick horizontal lines in the Indian-head test pattern can be used to show and to check this effect, by the intensity, polarity, and duration of the trailing smear. However, most horizontal lines, such as in the horizontal wedge, and horizontal portions of lettering, will show the effect.

Open peaking coils and coupling capacitors in the video amplifier can cause phase shift and smear, but it may also be due to transmission troubles. This can be determined by checking a second receiver; if both receivers show smearing, it is most likely due to the station.

Resolution or definition

Now we come to the final and most important application of the test pattern, its use in determining vertical and horizontal resolution.

In a general sense, if a picture is sharp and clear, and shows small details we say that it has good resolution, or high resolution. If the picture is soft and blurred, and small details are indistinct, we say that it has poor resolution, or low resolution.

Owing to the manner in which a television picture is "drawn", the definition from top to bottom is generally different from the definition sideways. With present TV standards the definition from top to bottom is somewhat better than that from left to right.

Consequently, in television we must distinguish between vertical and horizontal resolution, and accordingly we will treat each one separately.

Vertical resolution

The vertical resolution, (the resolution from top to bottom of the picture) is expressed in the number of horizontal lines that can be resolved. Therefore, we use the horizontal wedges in the test pattern to determine vertical resolution.

Vertical resolution depends primarily on the size of the kinescope spot. It does not depend on the high-frequency response or bandwidth of the receiver.

There are approximately 490 usable horizontal scanning lines (525 minus 7%, vertical blanking); the kinescope spot can be focused to a small enough size so that it can trace these 490 lines without overlapping, the maximum vertical resolution in 490 lines: actually, the effective resolution is considerably less than this and can be determined from the horizontal wedges.

Figure 6 will help in explaining the calibration and use of the horizontal wedges in a test pattern. There are 31 alternate black and white lines in this particular wedge. The left-hand edge of the wedge is 1/6th of the picture height. Considering only the left-hand edge of the wedge, we could fit 6 x 31 or 186 lines in the space between the top and bottom of the picture.

Considering only the right-hand edge of this same wedge, which is 1/12th of the picture height, we could fit 12 x 31 or 372 lines in the space between the top and bottom of the picture.

Therefore the left-hand edge of the wedge represents 186 lines, and the right-hand edge represents 372 lines.

Assume that when a test pattern with the wedge dimensions shown in Figure 6 is reproduced on a particular TV receiver, the separate lines in the wedge become blurred or indistinct at a point where the wedge is 1/10th of the picture height. This is equivalent to 10 x 31 or 310 lines. In this example we can state that the maximum vertical resolution is approximately 310 lines.

It should be noted that it is not customary to refer to frequency in regard to the horizontal wedges, or in regard to vertical resolution. However, as a point of interest, if the center line in the horizontal wedge extends for about 1/4th of the complete time for one horizontal scanning line, it is equivalent to 1 1/2 cycles of a 30-ko square-wave signal. The scanning lines cross the other lines in the horizontal wedge at various angles, equivalent to a maximum frequency of roughly one megacycle. The intensity or blackness of the horizontal wedge, compared to the vertical wedge, is therefore dependent on the low-frequency response of the receiver. If the low-frequency response is poor, the horizontal wedge may be grey when the vertical wedge is black.

Horizontal resolution

The vertical wedges are used to determine horizontal resolution. The horizontal resolution depends on the high-frequency response or bandwidth of the receiver, and also on the size of the kinescope spot.

In this example, the wedge has 31 alternate black and white lines. The top end of the wedge is 1/6 of the L. Therefore the equivalent number of lines at the top is 6 x 31 or 186. The bottom of the wedge is 1/12 of the L, so the equivalent number of lines is 12 x 31 or 372.

If this pattern is reproduced on a TV receiver, the separate lines in the vertical wedge might become blurred at the point where the wedge is 1/10th of the L. In this case, the maximum horizontal resolution is 10 x 31 or 310 lines.

2. The horizontal resolution may be expressed in frequency. This is very desirable in service work, because it indicates the effective bandwidth of the receiver.

The explanation involves some simple arithmetic:

The horizontal scanning frequency is 15,750 cycles per-second. One complete horizontal line takes 1/15,750 seconds, or approximately 63.5 microseconds, (milliseconds of a second). The horizontal blanking time is 1.8 microseconds so that time for the usable portion of one horizontal scanning line is 63.5 minus 10.2, or 53.3 microseconds.

The spot therefore requires 53.3 microseconds to travel from the left...
A receiver has a bandpass of 4 megacycles, which is traveled in 3/4 x 53.3, or 40 microseconds.

A video signal of one megacycle (Mc) produces one cycle in one microsecond. Each cycle has a negative half-cycle and a positive half-cycle, which when applied to the kinescope, produce a black dot and a white dot. Each cycle therefore produces two dots which we will consider as "lines".

In 40 microseconds, a one-megacycle signal produces 40 cycles, or 80 lines; 2 megacycles, 160 lines; 3 megacycles, 240 lines; 4 megacycles, 320 lines.

Horizontal resolution expressed in lines may be converted to frequency, by dividing the number of lines by 80. For example, if the maximum horizontal resolution of a set is 325 lines, the equivalent frequency or bandwidth is 325/80 or 4.06 Mc.

Conversely the horizontal resolution of a set in frequency (in megacycles) may be converted to equivalent lines, by multiplying the frequency (in megacycles) by 80. For example, if the maximum horizontal resolution of a receiver is 3 megacycles, the equivalent number of lines is 3 x 80, or 240 lines.

In the accompanying table, "Vertical Wedge Data", we have listed in columns 1 and 2 the corresponding lines and frequency for horizontal resolution.

Here are two examples in the application of this table:

1. On a particular TV receiver, the vertical wedge becomes blurred beyond 250 lines. What is the equivalent frequency, or bandwidth?
   Using columns 1 and 2, we find that 250 lines is equivalent to approximately 3 Mc.

2. A receiver has a bandpass of 4 Mc. How many lines should it resolve on the vertical wedge? Using column 2 and 1, we find that 4 Mc is equivalent to 320 lines.

**Wedge calibration**

On some test patterns, the equivalent number of lines is indicated by numbers at a few points on each wedge. It is a general practice to zero the last zero; so "20" means 200, etc.

In some test patterns, the wedges are not numbered but are marked by dots or other means at major steps.

For convenience, in Figure 8, we have shown the equivalent number of lines at each dot and at each end of the wedges for this NBC pattern.

In cases where the pattern does not indicate the number of lines, the information can usually be obtained from the TV station.

The equivalent number of lines at any point on either the horizontal or vertical wedges may be computed:

Multiply the number of black and white lines in the wedge, by the ratio of picture height to the width of the wedge, at the desired point on the wedge.

Even under the best conditions this is only an approximation, owing to inaccuracy in measuring the width of the wedge on the kinescope, and errors due to non-linearity.

The receiver must first be adjusted for the best possible linearity, with the test pattern just filling the mask, with a mask of the correct size and 3 x 4 proportions, and with contrast and focus set correctly.

**Single lines for horizontal resolution**

The single resolution lines in the Indian-head test pattern represent the width of a single line ranging from 50 to 575 lines.

Consider the thick line marked 50:

It would take 50 alternate black and white lines of this width to stretch across three-quarters of the full width of the picture.

It would take 575 alternate black and white lines of the width shown, for the single line marked 575, to fill three-quarters of the full width of the picture.

These single lines are intended to show "ringing", or damped oscillation at certain frequencies.

For example, assume that the video amplifier response rises at 3 megacycles and is then cut sharply. It will tend to ring at 3 Mc, when a signal containing this frequency is fed into the amplifier. The single line corresponding to 3 Mc or 240 lines, would provide the signal, and the resulting ringing or damped oscillation would be visible as several echoes of diminishing intensity following this and possibly adjacent lines.

The ringing should be evident at the right of the vertical wedge at a point along the wedge corresponding to 240 lines, or 3 Mc. However, it is better to observe and analyze the ringing on a single vertical line.

**Effect of regeneration on the vertical wedge**

If there is tendency toward regeneration at some particular frequency in the picture if amplifier, it may be evidenced by fine dark lines streaking horizontally across the vertical wedges at a point corresponding to this frequency.

For example, if the if amplifier is regenerative at a frequency 3 Mc removed from the picture if carrier frequency, the effect will be seen at a section along the wedge equivalent to 3 Mc, or 240 lines.

Regeneration depends on the gain of the if amplifier. Therefore it may be evident on a weak signal where the gain is high, and not evident on a strong signal where the gain is low.

When there is evidence of regeneration, the alignment, bypassing, and lead dress of the picture if amplifier should be checked in an effort to reduce or eliminate the regeneration.

**Practical rating of horizontal resolution**

In most test patterns, the wedges are not marked by numbers to indicate the equivalent number of lines along the wedge.

However, in television service work it is satisfactory to rate the horizontal resolution on the simple basis of "how far down" it is possible to distinguish the separate lines in the vertical wedge.

For instance, using the test pattern of the highest-definition station in the area, all receivers of a certain model may, when correctly aligned, resolve the lines in the vertical wedge "all the way down" to the narrow end of the wedge.

If a particular receiver of the same model does not give equally good resolution, it may need alignment, or other work.

On a cheaper model of receiver, with less bandwidth but with the same size picture tube, the vertical wedge in the same test pattern may be clear "down to within 3/4-inch" of the narrow end of the wedge.

This practical method of rating has already become rather widespread, but it is hoped that with increased knowledge of the subject, and possibly the standardization of wedge limits and markings, it will become common to note the horizontal resolution in frequency, and the vertical resolution in "lines". In fact, for TV receiver servicing it would be possible to omit the horizontal wedges and depend on the scanning lines structure as a check of vertical resolution.

**Precautions in checking horizontal resolution**

In using the vertical wedges on a test pattern to estimate the maximum horizontal resolution of a TV receiver, the following points must be remembered and considered:

1. The size and shape of the kinescope spot has a definite bearing on the apparent resolution, as pointed out in the section on focus.

2. Contrast and brightness must be set correctly, and not high enough to make the spot "bloom".

3. Reflections (echoes, ghosts) can reduce the apparent resolution of the receiver if they fall within the wedge.

4. "Snow" on a weak signal will reduce the definition. On a very weak signal, the entire vertical wedge may be blurred and indistinct; on a strong signal the same set may show excellent resolution.

5. A few TV stations use special, mental or temporary equipment-producing signals of low definition.

![Figure 7. Vertical wedge of pattern showing relation to overall picture size.](image1)

![Figure 8. The NBC Test Pattern, showing the equivalent frequency and number of lines at the major points on the wedges.](image2)
PART III

A high percentage of television service calls, possibly 80%, are due to troubles that can be located and corrected without requiring a great amount of technical knowledge, providing the technician has been adequately informed of the common troubles and their symptoms and remedies in the particular model of TV receiver.

The other 20% of service jobs require capable and resourceful technicians with thorough understanding of basic television principles and considerable practical experience. Serious technicians realize this fact and are continually striving for clearer understanding of basic principles.

In this series of articles, we will cover many essential television principles in the process of showing how to diagnose troubles. Two essential principles are included in the present article.

We recommend that readers purchase a copy of the author's booklet "Television Trouble-Shooting and Alignment" which has recently been published by the RCA Service Co., Inc., Camden, N. J. This booklet shows how to localize troubles, describes the requirements for TV alignment equipment, and gives illustrated step-by-step alignment instructions for two popular makes of TV receivers. (40 pages, 49 illustrations, price $1.00).

To check the over-all (rf, if, video) frequency and phase response of a television receiver, we would ordinarily need three pieces of laboratory equipment—

1. A square-wave video signal generator.
2. A high-frequency oscillator, amplitude modulated by the video generator.

When a test pattern is available, however, the over-all frequency and phase response of the television set can be checked quickly and conveniently by observation and analysis of the test pattern on the kinescope.

1. The wedges in the test pattern take the place of the square-wave video signals.
2. The TV station provides the rf signal, which is amplitude-modulated by the square-wave video signals of the wedges.
3. The kinescope takes the place of the wide-band oscilloscope.

Figure 1 shows both of these setups. The test pattern and the kinescope provide a very convenient and useful testing system for everyday TV service. But we must furnish the initiative, the persistence, and the time to learn how to use them.

Wedges are Video Signals

It is important to understand that the wedges in the transmitted test pattern are much more than a collection of black and white lines. They actually represent video signals ranging from about 30,000 to 4,000,000 cycles-per-second.

These video signals are generated in the camera tube and are used to amplitude-modulate the station's carrier. The transmitted video signals are square-wave at the lower frequencies, and essentially sine-wave at the higher frequencies.

The following simple analogy may help in understanding how the wedges are utilized at the transmitter in producing this wide range of video signals: When a boy runs a stick across a picket fence, he generates a noise, or an audible signal. The frequency of the signal depends on the speed of the stick and the number of pickets in a given distance.

Suppose the boy had a V-shaped trellis with 5 pickets, as shown in Figure 2. As he draws the stick across the pickets, the motion at the tip of the stick resembles a series of square waves. If the stick is drawn across at the top in one, second, it traces 5 square waves in one second, or a frequency of 5 cycles-per-second.

If the stick is drawn at the same speed across the bottom of the trellis, which is half the width of the top, it traces 5 square waves in 1/2 second. This is a rate of 10 cycles-per-second, double the previous frequency.

Figure 2. Analogy to vertical wedge in test pattern.

In an analogous manner, as shown in Figure 3, the camera tube at the TV transmitter produces an electrical square-wave signal as the electron beam in the camera tube is drawn across the image of the vertical wedge. But in this case the frequency is very high because the beam crosses the wedge in a few millionths of a second.

In this particular example, there are 10 black and 10 white lines in the wedge, equivalent to 10 cycles. (For simplicity, there is assumed to be a white line at the right-hand side of the wedge.)

At the top of the wedge, the beam crosses the 10 cycles in 5 millionths of a second, or 5 microseconds. In one microsecond, the beam crosses 2 cycles. This is equivalent to a rate of 2 million cycles-per-second, or 2 Mc.

At the bottom of the wedge, which in this example is half the width of the top, the beam crosses the 10 cycles in 1/2 the time, or in 2.5 microseconds. In one microsecond, the beam crosses 4 cycles. This is equivalent to a rate of 4 million cycles in one second, or 4 Mc.

When the beam scans across other points along the wedge, the generated frequency is between 2 and 4 Mc.

The horizontal wedge can be analyzed in the same manner, but for our purpose it is sufficient to know that in test patterns where the center line of the horizontal wedge is about 1/4 the length of a horizontal scanning line, it represents a half-cycle of a 30-kc square wave. In the RCA Indian-head pattern the horizontal lines (at bottom center) represent half-cycles of square-wave signals ranging from about 19 kc. to 0.6 Mc.

Signal-Wave Form vs Brightness

Electrical signals are changes in voltage during a period of time. Such signals are shown in books and on the screens of cathode-ray oscilloscopes, as "waveshapes" or "waveforms".

In radio, if we want to see the wave-form of audio-frequency signals, we must use an oscilloscope. In television we have a tremendous advantage because, without using an oscilloscope, we actually see each of the thousands of video signals that form the complete test pattern or picture. We see these signals not as waveshapes, but as changes in brightness along each scanning line on the kinescope. We see signals that last for as little as one-tenth of a millionth of a second; we see other signals that remain unchanged for as long as 53 millionths of a second.

To take advantage of this graphic display of the picture signals, we must understand the relation between the changes in brightness and the waveform of the signal that produces these changes: We must learn to look at any section of a
The following paragraphs briefly cover this subject:

The intensity of the electron beam in the kinescope, and consequently the brightness of the spot, depends on the voltage at any instant between the grid and cathode of the kinescope.

If we connect an electronic voltmeter between the grid and cathode of the kinescope, and vary the grid voltage, by means of the brightness control, we can observe how the brightness of the spot or raster changes as the grid voltage is changed. An arbitrary example of this relation is listed below:

<table>
<thead>
<tr>
<th>Grid Voltage (V)</th>
<th>Brightness</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 v</td>
<td>Bright (-white-)</td>
</tr>
<tr>
<td>-10 v</td>
<td>Light grey</td>
</tr>
<tr>
<td>-20 v</td>
<td>Medium grey</td>
</tr>
<tr>
<td>-30 v</td>
<td>Dark grey</td>
</tr>
<tr>
<td>-40 v</td>
<td>Black</td>
</tr>
</tbody>
</table>

(For simplicity, we are using a reference of zero volts for white.)

In the first three articles of this series we explained the function and the application of television test patterns in analyzing the response of television receivers. These articles contain a large amount of practical information which to the best of our knowledge is not available elsewhere.

We have now paved the way for the second major section of this series: Starting in this article, and continuing for several issues, we will analyze the effects of actual troubles with the graphic aid of several hundred photographs that have been made by the author specifically for these articles. These photographs clearly show how the picture or test pattern is affected by various faults in different sections of a typical television receiver.

**Portion of Patterns for Clarity**

Test pattern photographs are frequently printed in such a small size that most of the details are lost. It is not practical to use a magnifying glass to enlarge the printed reproduction because the detail involved in the half-tone printing process spoils the enlargement. If the photographs are printed in large enough size to make the details visible, only a small portion can be shown on each page. To overcome these limitations, the author is showing only a small portion of photographs in cases where it is necessary to observe the details. In this way it is possible to include numerous photographs on each page and yet maintain a sufficient size so that the reader can observe the desired effects.

For simplicity in this discussion, we are omitting reference to the sync pulses, which are 33% higher in voltage than the black signal level.

**Specially Designed Receiver**

The receiver used in making these photographs was specially designed and constructed to facilitate the work, and will be described in a later issue.

The receiver employs essentially the same circuits as the standard RCA Model 630TS, 8TS30, etc. Readers who wish to brush up on the function and action of the circuits in this type receiver, as an aid in studying the photographs, should obtain the 630TS service notes. Troubles in the horizontal deflection, vertical deflection, rf-video, sync, and power-supply sections.

**Video Troubles in This Issue**

The photographs in this issue show how the TV picture is affected by certain troubles in the video amplifier. The circuit of the amplifier is shown in Fig. 1. The caption under each photograph states the nature of the trouble and describes the principal effects that are evident in the picture.

Inspection of the photographs will show that the troubles selected for this issue affect the picture “quality” and are accompanied by “smearing” that ranges from a slight to a severe condition.

It must be mentioned that some of the troubles pictured here can be duplicated in part by incorrect conditions of rf alignment. These troubles will be covered in a later article.

Other troubles in the video amplifier, such as open coupling capacitors, open plate, screen, or cathode circuits, dead tubes, etc., will result in complete absence of the picture, or a very faint picture.

A third class of trouble in the video amplifier is caused by incorrect bias, which may be due to off-value resistors, leakage in coupling capacitors, etc.

Any serious trouble in the video amplifier may produce symptoms of sync failure. However, even when the picture is completely out of sync and will not remain stationary, it is possible to judge the picture quality and to determine from this, and from the appearance of the sync pulses, whether the trouble is due to incorrect rf-video response, or to a defect in the sync circuits.

**Other Troubles in Following Issues**

Study of the effects pictured in this and the succeeding articles will help to pave a smooth path to our goal, which is the development of a comprehensive troubleshooting procedure based on analysis of the picture.

In the following issues we will show photographs of the effects of troubles in the horizontal deflection, vertical deflection, rf-video, sync, and power-supply sections.
Fig. 1—Schematic of video amplifier as it appears in the special TV receiver used for these photographs. The illustrations in this article show how the picture quality is affected by various troubles in this circuit.

Fig. 2—This shows normal conditions. There is a slight trailing light-grey smear on the right-hand side of the lettering, and after the lines in horizontal wedge.

Fig. 3—Poor low-frequency response. 2nd-detector load resistor, not shown in schematic, dropped from 3900 to 100 ohms. Note trailing reversal, white after black, on right-hand side of lettering. Lettering and outer circle are not uniform black, as evident in cross-bar on letter T.

Fig. 4—Excessive low-frequency response and phase shift. 2nd-detector load resistor increased from 3900 to 100,000 ohms. Note smearing of lettering and horizontal wedge, and almost complete wiping out of vertical wedge.

Fig. 5—Low-frequency phase shift. 1st-video grid resistor dropped from 470,000 to 500 ohms. The contrast was turned down, brightness turned up, and vertical hold control adjusted to show vertical blanking and sync. Note trailing reversal after vertical sync, and after vertical blanking.
Fig. 6—Poor high-frequency response. 1st-video plate filter capacitor (10 uf) open, effectively increasing plate load resistor from 3300 to 10,100 ohms (3300 plus 6800). General smearing of wedges except center lines in horizontal wedge.

Fig. 7—Excessive high-frequency response. 1st- or 2nd-video plate load of 3300 ohms dropped to 1000 ohms. Reduces low-frequency response, exaggerating highs. Note trailing reversal, white followed by a fine dark line, after lettering.

Fig. 8—Excessive low-frequency response. 1st- or 2nd-video plate load of 3300 ohms increased to 16,000 ohms. Increases low-frequency response, decreases highs. General smearing of both wedges except center lines in horizontal wedge. Same general effect as shown in Figs. 4 and 6.

Fig. 9—Trailing reversal, white after black, produced by 2nd-video cathode resistor increasing from 330 ohms to 1500 ohms. Resulting incorrect bias makes it difficult to obtain suitable contrast.

Fig. 10—Hum in video, produced by heater-cathode leakage (700 ohms) in 2nd video stage. Hum voltage darkens some portions and lightens other portions of picture. Hum also gets into horizontal sync, distorting shape of picture.

Fig. 11—Loss of highs, and low-frequency phase shift produced by open coupling capacitor (0.05 uf) to the kinescope grid. Note that vertical wedge is practically wiped out. Note smear after lettering and after horizontal wedge.

Fig. 12—Believe it or not, this is a roller-skating rink. The smearing is not caused by trouble in the receiver, but by unusually poor TV relay conditions. Moral: Don't tear the set apart until reception has been checked on other stations or on other receivers.
PART V

How RF-IF Alignment Affects Picture Quality

In the previous issue, through the aid of numerous photographs that were made by the author especially for this series of articles, we showed how the picture quality is affected by various troubles in the video amplifier of a typical television receiver. In this issue, continuing the series of photographs, we show how the picture quality is affected by incorrect rf-if alignment.

The poor picture quality shown in Fig. 1 was produced simply by detuning one adjustment in the picture-if amplifier. The adjacent channel sound trap, normally 27.25 Mc in this particular receiver, was detuned to about 26 Mc. This reduced the gain of the amplifier near the picture-carrier frequency of 25.75 Mc, decreasing the amplitude of low-frequency modulation, and producing poor phase response.

Note in Fig. 1 that the longer horizontal lines, which represent low-frequency picture signals, are weak or grey, while the lines in the vertical wedges, which represent high-frequency signals, are stronger or blacker. Note that the outer circle, which should be a uniform black across any scanning line, is composed of seven different shades followed by a white trace (trailing reversal).

Because of the poor low-frequency response, the horizontal sync action is not good, as evidenced by sideways distortion in the shape of the circle. This distortion will vary with different scenes, and with motion of persons or objects in the picture. The effect is caused by picture signals “getting into” the sync. If the trap were tuned still closer to the picture-if of 25.75 Mc, the low-frequency signals would be virtually eliminated, and it would be impossible to hold the picture in sync.

Without alignment equipment (sweep, calibrator, and CRO), a technician might fumble around for days before locating the reasons for the poor picture quality shown in Fig. 1. Remember that this picture is the result of only one misadjustment.

It should be understood that incorrect rf-if alignment can cause other troubles in addition to poor picture quality. Incorrect alignment can produce unstable sync, inadequate blanking of the return lines, excessive noise in the picture, regeneration, and interference.

The numerous troubles that can originate in the rf, oscillator, converter, picture-if, second detector, and video amplifiers can be located quickly and easily with the aid of good alignment equipment.

Alignment equipment has particular interest for the writer, who has used a wide variety of such instruments during the last ten years, and has also designed several sweep-frequency generators and calibrators for special applications.

The writer recommends the RCA WR-30A Calibrator as being the writer, who has used a wide variety of such instruments during the last ten years, and has also designed several sweep-frequency generators and calibrators for special applications.

Low-frequency signals appear as a single sideband, spaced relatively far from the carrier.

With normal rf-if alignment in a TV receiver, the carrier is placed at about 50% or half-way down the slope of the response curve. On low-frequency signals, where there is only one sideband, it falls on the flat-top of the response curve, so it is amplified 100%. On low-frequency signals, both sidebands are received: One is amplified less than 50%, and the other is amplified more than 50%. For example, for some particular low-frequency picture signal, one sideband is amplified 40%, while the other is amplified 60%. At some higher signal frequency the gain is 10% and 90%, etc. The two sidebands add together to provide approximately 100% amplification.

Consequently, with normal rf-if alignment, the amplification is the same for both low-frequency and high-frequency picture signals. This type of response is generally desirable.

If the carrier is placed lower than 50%, the gain at low frequencies is reduced. If the carrier is placed higher than 50%, the gain at low frequencies is increased.

The principal picture components and the blanking and sync pulses, represent relatively low frequencies, but the sharp edges on these signals require good high-frequency response also.

In considering rf, the low-frequency picture signals are relatively close to the rf carrier. In considering if, the low-frequency picture signals are relatively close to the if carrier. The if carrier is usually at the high-frequency end of the if response band. The carrier frequency, rf or if, corresponds to zero frequency in the video amplifier.

Bandwidth is always measured from the carrier frequency to a point on the opposite slope; this point is usually taken as 50% down. It must be remembered that incorrect alignment is not always the primary reason for poor rf-if response. Off-value damping resistors (across the tuned circuits), open plate, screen, and grid-return bypass capacitors, open coupling capacitors, off-value coupling components, and regeneration, all affect the rf-if response. Abnormal bias on one or more of the rf-if tubes may cause poor response. This condition in turn may be due to a leaky coupling capacitor, or to a defect in the automatic gain control circuits, etc. Excessive input signal from a nearby TV station may necessitate biasing off several if tubes which also affects the frequency response.
Fig. 3—Picture carrier at 20%. Good picture quality. Signal-noise ratio not as good as for alignment in Fig. 2.

Fig. 4—Picture carrier at 10%. Poor low-frequency response, evidenced by the fact that horizontal wedge is lighter than vertical wedge. Poor sync, blanking, and signal-noise ratio.

Fig. 5—Picture carrier at 100%. Excessive low-frequency response, evidenced by the fact that horizontal wedge is darker than vertical wedge. Considerable smear after lettering.

Fig. 6—Narrow bandwidth. Note that the lines in vertical wedge are cut off beyond about 3 Mc.

Fig. 7—Narrow bandwidth, single peak response, with carrier at 50%. Vertical wedge becomes lighter beyond 3 Mc, but is not cut off sharply as in Fig. 6. Good signal-noise ratio.

Fig. 8—Similar to Fig. 7, but vertical wedge is much weaker due to position of carrier, and narrower bandwidth.

Fig. 9—Poor low-frequency response, evidenced by weak horizontal wedge. This was caused by tuning adjacent-channel sound trap close to picture carrier. Similar to Fig. 1.

Fig. 10—Poor response in general, caused by tuning adjacent-channel sound trap lower than picture carrier. Note leading smear on left-hand side of lettering.
The essential factor in successful television trouble-shooting is the ability to analyze any particular trouble as it appears in the picture or on the raster, and from this mental analysis to localize the trouble to one particular section of the receiver. From then on, it is usually a fairly simple matter to check the tubes, voltages, and components in the suspected section and to find the exact cause of trouble. Of course, if the trouble is due to incorrect rf-if alignment, it is necessary to use a sweep generator, calibrator, and CRO to realign the receiver.

In general, troubles in any particular section of a TV receiver produce effects in the picture, raster, or sound, characteristic of that particular section. Troubles in different sections produce different effects. The best way to explain and classify these effects is by means of photographs. For this reason the author has made several hundred photographs of screen patterns showing specific troubles. These pictures were made using the RCA Television Dynamic Demonstrator to facilitate the work. The trouble and causes as described apply to this basic type of television receiver circuit and not necessarily to others.

For the best results, we recommend that you obtain and study the author's RCA Television PICT-O-GUIDE (announced in this issue of RADIO SERVICE NEWS). Each PICT-O-GUIDE photo is reproduced with exceptional clarity on a special photographic type of card. They are systematically indexed and cover subjects and troubles which, in the main, we have not discussed elsewhere—due to space limitations and the type of paper and printing used.

In the two previous RADIO SERVICE NEWS issues we showed briefly how troubles in the horizontal-deflection and high-voltage circuit affect the raster or test pattern. This circuit, diagrammed in Fig. 1, is fed from the output of the horizontal oscillator. If the oscillator fails, there will be no input and, consequently, no high voltage. Without high voltage, there can be no raster or scanning lines visible on the kinescope.

Characteristic symptoms of trouble in horizontal-deflection circuits include:
1. Bright vertical bars on the raster.
2. Fold-over at the left-or right-hand side of raster.
3. Poor horizontal linearity that cannot be corrected by adjustment of the horizontal linearity, width, and drive controls.

Fig. 3—Same general cause as Fig. 2, but produced by reduction of resistor value to 50,000 ohms.

Fig. 4—Same trouble as Fig. 3, but with TV signal added to show effect on test pattern.

Fig. 5—Fold-over at right-hand side produced when the value of the grid resistor of the horizontal output tube is changed from 470,000 to 40,000 ohms.

Fig. 6—Bright vertical line at right, and picture expanded at left produced when the 0.035-uf capacitor in plate return of horizontal output tube is opened; drive control set full clockwise.

Fig. 7—Fold-over at left-hand side, produced by open 0.05-uf capacitor between cathode of horizontal damper tube and—100-volt bus.

Fig. 8—Same trouble as Fig. 7, but with TV signal added to show effect on test pattern.

Fig. 9—Small dim picture with fold-over at left produced when damper tube is removed from socket. This photograph was taken in a dark room with high line voltage applied to receiver. Normally, failure of damper tube causes complete absence of raster or picture.

Fig. 10—Picture stretched at left produced by open resistor across damper tube.
Fig. 11—Not all vertical lines are caused by trouble in the horizontal-deflection circuits. For example, the fine line at left—is caused by Barkhausen oscillation in the horizontal output tube. This interference is picked up in the input of the TV receiver. The effect is most evident on the higher channels when contrast control is turned up to maximum position.

Fig. 12—Normal expansion in picture size when brightness control is turned up. Turning up the brightness increases the kinescope beam current so that the voltage drop across the 1-megohm high-voltage filter resistor is increased and the accelerating voltage decreased. As a result of the decreased accelerating voltage, the beam is more easily deflected and the picture becomes larger.

Fig. 13—Same trouble as Fig. 11, but greater intensity. This effect may be minimized by adjusting the horizontal drive control, checking lead dress and shielding, and, in extreme cases, by replacing the horizontal output tube.

Part VII
Vertical Deflection Troubles

It may be helpful at this time to review the guiding principle behind this series of articles. This principle was outlined in the first issue, from which we quote:

"When something goes wrong in a television receiver, it generally shows up as a definite symptom in the picture. On no other type of electronic equipment are the troubles and symptoms so clearly displayed before our eyes. If we learn to recognize these visible symptoms, we can quickly localize the trouble to a particular portion of the set. For those who hope to become expert in television service, it will pay to study, observe, and learn how to analyze symptoms in the television picture... in this series of articles we will concentrate on diagnosing and localizing troubles by analyzing their effects on the picture."

We began this series of articles by showing how the vertical and horizontal wedges, which are incorporated in virtually every variety of TV test pattern, can be used to determine the frequency and phase response of the receiver. We then showed, by means of actual photographs, how typical troubles in the video amplifier affect the picture, how incorrect rf-if alignment affects the picture, how troubles in horizontal deflection affect the picture, and now in this issue, how troubles in vertical deflection affect the picture.

We do not expect the reader to be able to look at a faulty picture and say, "That must be R192, or C287½". We will feel that we have accomplished our aim when the reader can look at the picture and decide definitely that the fault lies in one particular section of the receiver. Sectionalizing, or localizing of the trouble is 90% of the job, because any one section of a TV receiver is relatively simple, consisting of only a few tubes and a handful of components. Once the fault has been accurately localized to one particular section of the receiver, the rest of the job is relatively simple and straightforward. The tubes can be checked by substituting new ones. The components and circuit voltages can be checked with a VoltOhmyst. The signal can be traced through the particular section with an oscilloscope, or "signal injection" may be used as outlined in this article.
The author has seen actual cases where much time was wasted by orienting the antenna and even installing new antennas in an effort to eliminate multiple pictures and "ghosts" that were due in one case to the horizontal oscillator being off frequency, and in several other cases, to incorrect rf-if alignment. These instances emphasize the need for accurate analysis and localization of troubles.

By reviewing the pictures that we have published thus far, the observant reader will note the following important facts as an aid in sectionalizing troubles:

1. Pronounced streaking or smearing is due to troubles in the video amplifier section.
2. Poor definition is generally due to incorrect alignment of the rf-if sections.
3. Foldover on the left- or right-hand sides of the raster, or bright vertical bars, are due to troubles in the horizontal deflection coils.
4. Foldover on the top or bottom is due to troubles in the vertical deflection section.
5. Keystoning on a direct-view electro-magnetically deflected kinescope is due to open or short circuits in the deflection coils.

**Fig. 2.** Absence of vertical deflection. All of the horizontal scanning lines (approximately 500) are compressed into a single bright horizontal line. This photograph was made with a "dead" vertical output tube. The same effect is produced by failure of the vertical oscillator, by an open coupling capacitor between the vertical oscillator and the vertical output tubes, by an open winding in the vertical output transformer, or by an open circuit in both halves of the vertical deflection coil.

**Fig. 3.** When there is no vertical deflection, a quick check on the vertical output section can be made by introducing 60-cycle ac into the grid of the vertical output tube. When this picture was made the coupling capacitor between the vertical oscillator and the vertical output tubes was opened, and 60-cycle voltage was introduced into the grid of the output tube by placing a finger on the grid. The hum voltage picked up by the body is usually sufficient to produce some vertical deflection as shown above. Note in this picture that the test pattern appears to be wrapped around a cylinder, due to the sine-wave deflection. This simple check shows that the vertical output circuit, including the tube, output transformer, and vertical deflection coils, are in operating condition, thereby indicating that the trouble is ahead of the vertical output tube. As mentioned previously, the fault in this case was an open coupling capacitor between the vertical oscillator and output tubes. This system of "signal injection" to find troubles quickly in the vertical deflection circuit can be extended and improved by using a good audio oscillator, such as the RCA W-25A4 to provide a 60-cycle sine-wave signal of adjustable amplitude. First feed the audio oscillator directly across the vertical deflection coils, then into the grid circuit of the vertical output tube, and finally into the output circuit of the vertical oscillator. Absence of vertical deflection on the kinescope at any one of these test points will reveal the location of the trouble.

**Fig. 4.** When the raster or test pattern on a directly viewed kinescope has a trapezoidal or keystone shape, the trouble is usually due to a short circuit or open circuit in the deflection coils. In this photograph, one half of the vertical deflection coil is shorted.

**Fig. 5.** Same effect as in Fig. 4, but the other half of the vertical deflection coil is shorted, causing keystoning in the opposite direction.

**Fig. 6.** Keystoning due to an open circuit in one half of the vertical deflection coil.

**Fig. 7.** Keystoning produced by a short circuit across one half of the horizontal deflection coils. This photograph is included in this issue so the reader may compare it with Figures 4, 5, and 6.
Fig. 8. Damped ripple (ripple of decreasing amplitude) on left-hand side of each horizontal scanning line, produced by open resistor across both sections of the vertical deflecting coil. This damped oscillation occurs in the horizontal deflecting circuit and it is coupled into the vertical deflecting circuit. The resistors across the vertical deflection coils prevent the ripple from becoming evident.

Fig. 9. In addition to the ripple shown in Fig. 7, faint dark vertical bars are produced on the left-hand side of the raster when both of the resistors across the vertical deflecting coils are opened. These bars show up more clearly on the raster alone in this photograph than on the test pattern of Fig. 8.

Fig. 10. Foldover or brightness at top of raster produced by heater-cathode leakage in the vertical output tube.

Fig. 11. Insufficient height and poor vertical linearity may be due to incorrect value of the vertical discharge capacitor (0.05 uf), or to open electrolytic capacitors in the cathode and plate circuits of the vertical output tube.

Fig. 12. Foldover at bottom produced by leakage across the coupling capacitor between the vertical oscillator and the vertical output tubes, or by a low value grid resistor in the vertical output tube. When this photograph was made the vertical linearity control was adjusted to make the horizontal scanning line structure clearly evident. Note that each white horizontal scanning line becomes thinner to produce the effect of black inner circles and on the lines of the vertical oscillator. It may also be observed in this photograph that there is some tendency toward "pairing" of the interlaced sets of lines. That is, the 2nd and 3rd lines are closer together than the 3rd and 4th, etc.

**PART VIII**

**Vertical Oscillator Troubles**

In a previous article dealing with vertical deflection troubles, it was pointed out that when the vertical oscillator fails to operate correctly, there is no vertical deflection. It was shown that this trouble is evidenced by a single bright horizontal line on the kinescope.

When the output of the vertical oscillator is weak it may be impossible to obtain sufficient height with good vertical linearity. The activity of the vertical oscillator can be checked quickly and easily by measuring, with an RCA Volt-Ohmyst, the developed negative bias on the grid of the oscillator tube. The use of an electronic voltmeter such as the Volt-Ohmyst is necessary because it does not affect the operation of the oscillator circuit. In a circuit such as that given in Fig. 1, the developed bias can be measured between the grid of the oscillator tube and the junction of the vertical-hold control and the 2.2-megohm resistor.

A further trouble in the vertical oscillator is incorrect frequency. The impossibility, by careful adjustment of the vertical hold control, of getting one (and only one) complete picture from top to bottom, is a reasonably definite indication that the frequency, or blocking rate, of the vertical oscillator is either too high or too low. The correct frequency is 60 cycles per second.

Effects of various incorrect frequencies are shown in the accompanying photographs. In each of the cases pictured here, the vertical hold control was adjusted to obtain a stationary pattern. At other settings of the vertical hold control, the picture rolls up or down.

There is frequently confusion as to whether troubles such as those illustrated here are due to faulty sync, or to incorrect frequency of the vertical oscillator. A decision can be made quickly by "killing" the sync and "free-wheeling" the vertical oscillator, as follows:

1. Remove the sync input to the vertical oscillator. One way to do this is to open the coupling capacitor from the sync section. This capacitor, as shown in Fig. 1 at left side is 0.01 uf in value.

2. Slowly adjust the vertical hold control. If at some critical setting it is possible to obtain one (and only one) complete picture from top to bottom, and hold it almost stationary by careful adjustment of the control, it is a definite indication that the frequency of the vertical oscillator can be adjusted correctly. Naturally, the hold control in this case should not be too near the extreme end of its range because there may not be enough range of adjustment when sync is again applied.

3. If it is not possible to obtain one complete picture at any setting of the vertical hold control, it is a definite indication that the frequency of the vertical oscillator cannot be adjusted to the correct rate of 60 cycles per second. If the reader studies the accompanying photographs and explanations he should have no difficulty in recognising and understanding the symptoms of incorrect vertical frequency.
Fig. 1—Vertical oscillator and vertical deflection section of the television receiver used in producing the troubles shown in accompanying photographs. The frequency or blocking rate of the vertical oscillator is largely dependent on the RC time constant in the grid circuit. The value of resistance in the grid circuit is adjustable by means of the vertical hold control. The correct free-running blocking rate is slightly less than 60 cycles per second. Incoming vertical sync pulses serve to trigger the vertical oscillator, keeping it in step or in sync with the vertical deflection of the TV transmitter.

Fig. 2—The presence of two complete pictures indicates that the electron beam in the kinescope is being deflected from top to bottom in 1/30th second, or that the frequency or blocking rate of the vertical oscillator is 30 instead of 60 cycles per second. This condition was produced by increasing the value of the 1.5-megohm resistor in the oscillator grid circuit to 3 megohms, and by adjusting the vertical hold control to obtain a stationary picture. This effect is accompanied by flicker and lack of interlace.

Fig. 3—The presence of three complete pictures indicates that the electron beam in the kinescope is being deflected from top to bottom in 1/20th second, or that the frequency or blocking rate of the vertical oscillator is 20 instead of 60 cycles per second. This condition was produced by increasing the value of the 1.5-megohm resistor in the oscillator grid circuit to approximately 6 megohms and by adjusting the vertical hold control to obtain a stationary picture. This effect is accompanied by flicker and lack of interlace.

Fig. 4—The presence of two superimposed half-pictures indicates that the electron beam in the kinescope is being deflected from top to bottom in 1/120th second, or that the frequency or blocking rate of the vertical oscillator is 120 instead of 60 cycles per second. This condition was produced by shorting across the 1.5-megohm resistor in the oscillator grid circuit and by adjusting the hold control for a stationary picture.

Fig. 5—Same trouble as in Fig. 4, but with the hold control readjusted for a different blocking rate. When the frequency of the vertical oscillator is either too high or too low, the effect that is seen on the kinescope varies with adjustment of the vertical hold control. Usually, the picture appears to rotate vertically except at one or more definite settings of the vertical hold control. Under some conditions of trouble, the picture cannot be held stationary at any setting of the hold control.
PART IX
Blanking and Synchronizing Signals

It is now generally recognized that the majority of troubles in television receivers can be localized to a particular section of the receiver by correctly interpreting the symptoms displayed in the picture on the kinescope. It is not equally well known that the blanking, and synchronizing signals, which normally are not visible on the kinescope, but which can easily be brought into view, provide a positive means for localizing sync troubles and for checking incorrect blanking.

To take full advantage of the information that can be obtained from visual inspection of the blanking and synchronizing signals, it is necessary to have a reasonably good knowledge of the relative signal amplitudes and time elements involved. We are, therefore, devoting this issue to a brief study of the blanking and synchronizing signals.

Specially-Prepared Chart

To simplify the study of blanking and synchronizing signals, we have prepared a special chart, Fig. 2, in which the signals are drawn to scale and arranged in line-under-line sequence for ease in comparing with the same signals as they appear on the kinescope. Television students and instructors will find that this chart, together with the accompanying photographs, is much easier to understand and is, therefore, more effective than the conventional "synchronizing waveform" charts that have been used up to now.

The chart shows the waveform of signal voltage for each line of vertical blanking and sync in each of the two interlaced fields, which are identified as "A" and "B" for convenient reference. Waveforms for all-white and all-black picture lines are shown at the top of the chart; the actual waveform on each picture line depends on the televised scene.

As a further aid to the reader, we are including several unusual photographs (Fig. 5, 6, 10) that were made with a relatively high shutter speed of 1/100 second in order to show some of the lines in a single field. In 1/100 second, the electron beam in the kinescope traces about 160 of the full 525 lines.

In studying the chart in Fig. 2, the following points should be noted:

1. The Total number of horizontal scanning lines is 525. There are approximately 490 picture lines and 35 lines of vertical blanking and sync. Half of these lines are in field A and half in field B. There is a permissible plus and minus tolerance in the number of lines of vertical blanking, with a similar tolerance in the number of picture lines to maintain the total at 525.

2. The relative amplitude of the signal voltages along each line is indicated by the figures 1.00, 0.75, 0.50, 0.25, and 0, adjacent to the top lines, corresponding to signal voltages of 100%, 75%, 50%, 25%, and zero. These figures are shown only on the top lines, but they apply to all lines.

Signal amplitudes higher than approximately 70% produce black. Signal amplitudes of approximately 15% or less produce white. Amplitudes between 15% and 70% produce various shades ranging from light grey to dark grey respectively. With correct adjustment of contrast and brightness, when the signal from the transmitter is greater than approximately 70% of its maximum voltage, the electron beam in the kinescope and the spot of light on the kinescope screen are blanked out. The spot, therefore, is blanked out for the duration of the blanking and sync signals.

3. Horizontal and vertical fly back occur during the respective blanking intervals. The beam is deflected rapidly from right to left during a portion of the horizontal blanking time. The beam is moved rapidly from bottom to top at a portion of the vertical blanking time.

4. The duration of the horizontal scanning lines and of the blanking and sync signals can be determined from the microsecond scale shown at the bottom of each field:

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Fig. 6—Effect similar to Fig. 4 and 5, but produced by opening the 100,000-ohm resistor which is connected between the vertical hold control and the minus 100-volt bus. The chart shown in Fig. 6, 5, and 6 can be distinguished by leakage across the grid capacitor of the vertical oscillator, by a low-value grid capacitor, and by other troubles in the vertical oscillator circuit. Fortunately, the vertical oscillator and discharge circuit contains only a few components which can be checked quickly with a Fault Finder to locate the faulty unit.

Fig. 7—The effect shown above was produced by opening either the 0.05-μf capacitor or the 100-ohm series resistor in the plate circuit of the vertical oscillator and discharge tube. In normal operation, the saw-tooth voltage for the vertical output tube is generated across this capacitor. When the capacitor is open, the voltage on the plate of the discharge tube rises very rapidly instead of gradually. This rapid rise, and the normal rapid discharge, produces rapid vertical deflection of the electron beam in the kinescope, even if the blocking rate is correct. As a result, all of the scanning lines, which should be nearly horizontal, have a decided slope.

Fig. 8—Same trouble as in Fig. 7 but with a different setting of the vertical hold control. It is suggested that the reader duplicate the troubles shown in these photographs, and study the resulting symptoms displayed on the kinescope, particularly noting the wide variety of effects that are produced by adjusting the vertical hold control in each case. For classroom or other instructional purposes, the hold control and the 15-megohm series resistor may be replaced with a 10-megohm potentiometer to permit changing the vertical oscillator frequency over a wide range.

Fig. 1. Block diagram showing the path of sync signals from the antenna to the kinescope. By learning to interpret the relative amplitude of sync signals as they appear on the kinescope, it is possible to tell—1. Whether faulty sync is due to trouble in stages to the left of the kinescope or to trouble below the receiver in the r-f system. 2. Whether vertical blanking trouble is due to insufficient low-frequency response in the r-f video amplifier. 3. Whether horizontal blanking troubles are due to poor frequency response or to incorrect horizontal sync phasing.
5. The waveform of horizontal blanking and sync for each of the approximately 490 picture lines is shown at the top of each field in Fig. 2, and in more detail in Fig. 7.

6. Horizontal sync on lines 6 to 11 is obtained by the rise in signal voltage from 75% to 100% near the right-hand side of these lines. Note that the leading edge of each horizontal sync pulse starts at the same instant in each line.

7. Vertical sync in field B starts near the center of line 7. This difference may be noted also by careful inspection of Fig. 5 and 6. The time interval (1/60 second) between the start of vertical sync is precisely the same in successive fields. It is this fact, combined with the odd number (525) of horizontal scanning lines, that provides interlacing of the two fields.

8. Equalizing pulses are provided near the center of lines 1 to 18 to compensate for a difference in sync voltage conditions at the start of vertical sync in the two fields. In field A, the start of vertical sync is one-half line from the preceding horizontal sync pulse. In field B, the start of vertical sync coincides with the horizontal sync pulse at the end of line 6. The equalizing pulses, by their effect in the vertical integrating circuit, serve to smooth out the difference in signal-voltage conditions at the start of alternate fields, thus permitting the vertical oscillator to be triggered at exactly uniform time intervals from field to field. Even a slight difference in the time interval from one field to the next would result in imperfect interlacing.

Practical Pointers

Here are some important practical facts about blanking and sync signals:

A. The vertical blanking signal can be brought into view on the kinescope by carefully adjusting the vertical hold control so that the picture moves slowly downward out of sync. The horizontal blanking signals can be brought into view by adjusting the horizontal sync phasing control (if there is such a control on the receiver) or, in some sets, by adjusting the horizontal hold control.

To observe and check the relative amplitude of blanking and sync signals, it is necessary to reduce the contrast (not enough to lose sync) and increase the brightness until the sync becomes just blank. Under this condition, in a normal receiver the blanking becomes grey, as shown in Fig. 3, 7, and 8.

When sync troubles are analyzed, it is sufficient for most purposes to view only the vertical blanking and sync signals which, as mentioned previously, can be brought into view easily and quickly by means of the vertical hold control.

B. In a normal receiver, the blanking signals are slightly darker than the darkest picture signals, and the sync is decidedly darker than the blanking, as shown in Fig. 3.

C. If blanking is as light as, or lighter than, the darkest picture signals, it will be difficult or impossible to blank out the vertical return lines at normal contrast settings. (The vertical return lines slope upward from left to right across the picture). Poor vertical blanking is usually caused by insufficient low-frequency response in the video amplifier. It may also be caused by poor low-frequency response in the rf-if amplifier due to the picture carrier being too low on the slope of the response curve.
D. The horizontal phase and hold controls should be adjusted to obtain approximately equal amounts of blanking signal at the left- and right-hand sides of the picture. The horizontal blanking on each side of the picture can be brought into view by temporarily shifting the centering control or the focusing coil. In order to see the blanking signals, it is necessary to adjust contrast and brightness so that sync becomes dark grey. Horizontal sync is to be considered as part of horizontal blanking when the picture is being adjusted for equal blanking on both sides.

If there is no blanking on one side of the picture, a portion of each horizontal return line will be unblanked. Picture signals on the unblanked portions will appear as faint and indefinite forms that are most evident in black areas of the picture. This trouble will not be present if there is some amount of horizontal blanking on each side of the picture.

E. The kinescope serves as a monitor to show whether poor sync action is due to trouble in circuits ahead of the kinescope or beyond it, as indicated in Fig. 1.

In case of sync trouble, the first step is to inspect the vertical sync and blanking signals as they appear on the kinescope. If the sync is normal, that is, if it is definitely darker than the blanking and the darkest picture elements, it may be assumed that the trouble is in the circuits between the video amplifier and the deflection oscillators. If the sync is not normal, that is, if it is not definitely darker than the blanking and picture signals, the trouble is in the rf, if, or video amplifier. The trouble in this case may be due to poor low-frequency response in the video amplifier, poor rf-if alignment, or undesired limiting action in the video amplifier.

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VERTICAL EQUALIZING PULSES

Fig. 3—Vertical blanking and sync, showing only a portion of the total width of these signals. The blanking should be slightly darker than the darkest picture elements, and sync should be definitely darker than the blanking. Refer to detailed views in Figs. 4, 5, and 6.

Fig. 4—Portion of vertical blanking and sync, including equalizing pulses. This photograph shows both fields, with a total of approximately 39 lines of vertical blanking. The lines are numbered to correspond with Fig. 2.

Fig. 5—Same as Fig. 4, but showing field A only. (The photographs in Figs. 5 and 6 were made with a camera shutter speed of 1/100 second.)

Fig. 6—Same as Fig. 4, but showing field B only.

Fig. 7—Photograph of horizontal blanking and sync signals.
**PART X**

**More on Horizontal-Deflection Troubles**

This article covers additional horizontal-deflection troubles, including those that are encountered in the "direct" deflection type of circuit. This circuit, Fig. 1, is used in many receivers of recent design.

As shown in the July, 1949 issue of RCA Radio Service News and, in greater detail, in the RCA Picture-O-Guide, most of the troubles in the horizontal-deflection circuit of a television receiver produce, in the picture, one or more of the following visual symptoms:

1. Insufficient width, excessive width, or poor horizontal linearity.
2. Bright or dark vertical bars on the raster.
3. Fold-over at left- or right-hand sides of the raster.
4. Absence of raster, due to lack of high-voltage.

Failure of the horizontal oscillator, discharge, or output circuits, or their supply voltages, will result in failure of the high voltage. When the high voltage fails, either partially or completely, there is a complete absence of a raster or a picture on the kinescope.

**Insufficient Width**

Insufficient width may be due to one or more of the following items:

1. Reduced amplitude of the output signal from the horizontal oscillator. (The horizontal-deflection signal is generated in the horizontal oscillator which acts through the horizontal discharge and output circuits to energize the horizontal-deflection coils.) Weak output from the horizontal oscillator may be due to a defective tube or other component, or reduced plate voltage in the oscillator circuit.
2. A weak tube, a defective component, or reduced plate voltage in the horizontal-discharge or horizontal-output circuits.
3. Low line voltage, a weak power rectifier, or other defect in the B+ circuit.

**Reduced Line Voltage**

The effect of reduced line voltage on the size of the picture is shown in the three superimposed photographs of Fig. 2, which were taken at three different values of line voltage: 125, 115, and 105 volts. (The brightness control was readjusted slightly in each case to maintain approximately the same brightness level. Other controls were not touched.) The receiver under test had automatic gain control so it was unnecessary to adjust the contrast control.

The fact that it is possible to increase the height of the picture beyond the top and bottom of the picture tube should not be regarded as an indication that the line voltage and B+ voltages are adequate. Although a television receiver may appear to have more reserve power available for vertical deflection than is ever required in actual use, even at the lowest probable line voltage; actually, this reserve power may not be usable.

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*An RCA TV Isotap, WP-25A, was used to obtain the three different voltages.*

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**Fig. 1.** "Direct" horizontal-deflection circuit used in RCA model T164 and many other recent models. Note that the horizontal-deflection coils are connected in series with the plate winding of the high-voltage transformer, which is an air-core type. In earlier models, the horizontal-deflection coils are connected to a secondary winding on an iron-core, high-voltage transformer. This RCA direct-deflection type of circuit has higher power efficiency than earlier circuits.
be usable because the linearity of the picture obtained with extended vertical deflection probably would be unacceptable. On the other hand, there is comparatively little reserve power available for extra horizontal deflection even at normal line voltage. Although low line voltage is seldom a problem in obtaining sufficient vertical deflection, it may be one of the causes of insufficient width.

**Obtaining Increased Width**

Occasionally it is necessary to obtain more width than was provided in the original design of the receiver. For example, more width is required when the mask is changed from a straight-sided shape to one with curved sides. In such cases of insufficient reserve power for the extra horizontal deflection, it is necessary to alter the deflection circuit slightly. In horizontal-deflection circuit similar to that used in the RCA model 630TS, additional width can be obtained by connecting a capacitor of approximately 0.05 µf across the width coil, or by opening the width coil. The effect of opening the width coil in this deflection circuit is shown in Fig. 5. In some projection-type receivers, it is possible to obtain appreciable increases in width and height by moving the deflection yoke slightly back toward the socket-end of the picture tube. This expedient is seldom practical on other types of receivers due to beam cutoff by the neck of the tube.

To locate the cause of insufficient width, it is advisable to first try new tubes in the horizontal oscillator, discharge, output, and damper circuits, and in the B+ rectifier circuit. Also check the line voltage. If the line voltage is normal, and if a new tube does not correct the condition, it is necessary to check the voltages and components in the horizontal oscillator and deflection circuits. If possible, check the peak-to-peak input and output voltage of each tube in the horizontal circuits, using a good cathode-ray oscilloscope, such as the RCA WO-57A, or an electronic voltmeter that can read peak-to-peak voltage, such as the RCA WV-97A.

**Fig. 2. Effect of line voltage on picture width and height is shown by these three superimposed photographs taken with line voltages of 105, 115, and 125 volts.** The picture size is smallest with 105 volts, and largest with 125 volts. When sufficient width cannot be obtained by means of the width and drive adjustments, it is advisable to check the line voltage.

**Fig. 3. Fold-over at left due to short-circuited width coil in RCA 630TS.**

**Fig. 4. Ringing in horizontal-deflection circuit, evidenced by vertical bars at left side of raster, due to open 28-µf capacitor across one-half of horizontal-deflection coil in the "direct" horizontal-deflection circuit of Fig. 1.**

**Fig. 5. Effect on width of picture produced by adjustment of width coil in model 630TS type of horizontal-deflection circuit.**

a. Coil adjusted for minimum width.
b. Coil adjusted for maximum width.
c. Increased width, obtained by opening the width coil, with some sacrifice in horizontal linearity.

**Fig. 6. Fold-over and bright vertical bars produced by an open 0.018-µf capacitor in the damper circuit of Fig. 1.**

**Fig. 7. Extremely narrow picture produced by a shorted 0.018-µf capacitor in the damper circuit of Fig. 1.**

**Fig. 8. Narrow picture produced by an open 0.022-µf capacitor in the damper circuit of Fig. 1.**

**Fig. 9. Fold-over at left and narrow picture produced by a shorted 0.022-µf capacitor in the damper circuit.**

**Fig. 10. Narrow picture width produced by an open linearity coil in the damper circuit of Fig. 1.** This fault may affect the horizontal-output tube and the 12,000-ohm screen resistor, and result in complete absence of raster. Circuit shown in Fig. 1.
PART XI

Automatic-Gain-Control Troubles

Automatic gain control (AGC) in the television receiver regulates the gain of the rf and picture-if amplifiers in order to maintain approximately the same peak amplitude of signal input to the picture second detector and video amplifier on weak, medium, and strong TV signals. The AGC is normally inoperative on extremely weak signals.

The gain of the rf and picture-if amplifiers is controlled by varying the negative grid bias on some of the tubes in these amplifiers. The controlling negative bias voltages are furnished by the AGC circuit.

Typical symptoms of AGC trouble include:

1. Loss of picture and sound, caused by excessive magnitude of the negative bias voltage from the AGC circuit; this bias cuts off the rf and picture-if amplifiers, thereby preventing the passage of signals.

2. Horizontal pulling in picture, as shown in Fig. 2, caused by compression of sync amplitude due to insufficient bias voltage from the AGC circuit. This results in excessive rf or if gain and excessive signal input to the video amplifier.

3. Overloading on strong TV picture signals, as shown in Fig. 3, caused by incorrect setting of AGC threshold adjustment, or trouble in the AGC circuit.

Some AGC circuits include a threshold adjustment that must be set correctly to avoid both excessive and insufficient gain in the rf and picture-if amplifiers. Effects of incorrect adjustment are shown in Figures 2, 3, 6, and 7.

In receivers where the input signal to the AGC circuit is taken directly (not through a blocking capacitor) from a direct-coupled video amplifier, certain troubles in the video amplifier can cause excessive negative bias voltages to be delivered by the AGC circuit. In such receivers, a trouble in the video amplifier may result not only in loss of picture, and possibly the raster, but also in loss of sound.

There are many different varieties of AGC trouble, some obvious, and some obscure. Very frequently the obvious symptoms of trouble appear to have no possible connexion with the AGC circuit. The technician’s salvation in such cases is the fact that it is always possible to override the AGC voltages temporarily by means of an external battery and potentiometer. In many cases the use of a battery and potentiometer will restore the picture, or sound, or both, and thereby permit an intelligent diagnosis of the trouble. When both the picture and sound are missing, it may be difficult to begin localizing the fault.

The battery and potentiometer should be connected as shown in Fig. 4. The visible symptoms of AGC trouble are frequently misleading. For this reason, a “bias box”, connected as shown above, is extremely helpful in determining whether the AGC circuit is at fault. The bias box is used to override the bias voltages furnished by the AGC circuit.

It is advisable to make a habit of checking the AGC voltages on both weak and strong signals. The voltages should be measured at the grids of the controlled tubes and also at the output of the AGC circuit, in order to reveal possible troubles between these points. An RCA Volt-Ohmmist such as the WV-97A is recommended for AGC measurements because its isolating probe introduces negligible resistive and capacitive loading in the grid circuits.
Visible Symptoms of Hum Trouble

Undesired hum voltages in a television receiver may produce either visible or audible symptoms, or a combination of both. This article covers the localization of hum troubles that produce visible symptoms in the picture, with or without any accompanying audible effects.

Success in visual analysis of hum troubles depends on the correct answers to the following questions:

1. Do the visible hum symptoms occur at 60 cycles, or at 120 cycles?
2. Are there changes of brightness (one or two cycles of hum bars*) between the top and bottom of the picture?
3. Is there horizontal pulling (one or two cycles) between the top and bottom of the picture?
4. Are the symptoms in items 2 and 3 both present in the picture?
5. Do the visible symptoms in items 2 and 3 remain in view on the raster, or disappear, when the picture signal is removed?
6. Are the visible symptoms accompanied by excessive audible hum from the speaker?

*Each of these symptoms furnishes a definite clue, and the combination of such clues generally points unerringly to a particular section of the receiver. After the trouble has been localized, a routine check of the tubes, (and other components) and voltages in the suspected section will reveal the exact fault.

Two Principal Types of Hum Symptoms

One of the first steps in localizing the source of hum trouble is to determine, from an analysis of the visible symptoms, whether the hum is occurring at a 60- or 120-cycle rate.

Ham at a 60-cycle rate generally indicates heater-cathode leakage in a tube. Ham at a 120-cycle rate usually indicates trouble in the B-supply circuit.

A few exceptions to these general rules are mentioned later.

For simplicity in this article, it is assumed that the receiver is operated from a 60-cycle supply, in which case the visible hum symptoms occur at either 60 or 120 cycles per second. If the receiver is operated on a 50-cycle supply, which is used in some areas, the hum symptoms will occur at 50 or 100 cycles. When the receiver is operated through an inverter from a dc supply, the rate of any visible hum symptoms depends on the frequency of the inverter output.

120-Cycle Hum Symptoms

Most television receivers utilize full-wave rectification in the B-supply circuit. The output of a full-wave rectifier, operating from a 60-cycle supply, consists of 120-cycle pulsating dc. The pulsations are normally smoothed into pure dc by the action of filter capacitors and chokes. However, if there are any serious defects in the filtering circuits, such as open filter capacitors, some or all of the B+ and B- voltages will have excessive 120-cycle ripple, or variation in voltage, which may produce 120 cycle hum trouble in several sections of the receiver.

Open filter capacitors in the B-filter circuit produced the visible

*hum bar is a change in brightness between the top and bottom of the picture or raster. See Fig. 1.

Fig. 1. Two cycles of change in width, and two cycles of change in brightness (hum bars) between the top and bottom of the raster at a 120-cycle rate. Figures 2 to 9 show examples of 60-cycle hum trouble caused by heater-cathode leakage.

Fig. 2. One cycle of change in brightness (60-cycle hum bars) and one cycle of horizontal pulling, between top and bottom of picture, indicates heater-cathode leakage in the rf, if, or video amplifiers. The trouble in this example was caused by a defective tube in the picture-if amplifier. The 60-cycle leakage current flows through the cathode resistor and modulates the TV signal. The position of the hum symptoms is shifted, as shown above at left and right by reversing the power-cord plug.

Fig. 3. The presence of 60-cycle hum bars on the raster alone (without TV or other signal) indicates heater-cathode leakage in the video amplifier section, which includes the 2nd detector, dc restorer, and kinescope. Normally, the vertical oscillator tends to sync on the leading edge of the dark bar, as shown above at left. The entire dark bar may be brought into view by adjusting the vertical hold control, as shown above at right. The leakage in this example was simulated by connecting a 1000-ohm resistor from the cathode to the ungrounded heater terminal in a video stage that has a 330-ohm cathode resistor. (Refer to Fig. 5.)
hum symptoms shown in Fig. 1, where there are two cycles of change in the amplitude of horizontal deflection (two cycles of variation in the length of the horizontal scanning lines), between the top and bottom of the raster. Also, there are two cycles of hum bars, or graduation in brightness, between the top and bottom of the raster.

When the photograph for Fig. 1 was made, the vertical-hole control was adjusted for the correct vertical-deflection rate of 60 cycles while a TV station was received, and the rf gain was reduced until the TV picture became invisible, leaving only the raster in sight on the kinescope. As the gain was reduced, the vertical-hole control was adjusted to maintain the vertical-deflection rate of 60 cycles. There are two cycles of change in width (and also in brightness) in 1/60th second, indicating that the hum voltage is occurring at 120 cycles per second, and that the trouble, therefore, is in the B-supply filter circuit. If the hum symptoms occurred at 60 cycles, there would be only one cycle of change in width (and brightness) between the top and bottom of the raster.

Excessive hum voltage on some or all of the B-output taps usually affects more than one section of the receiver, and results in some or all of the following symptoms.

1. Excessive audible hum from the speaker, caused by hum voltage on the B+ or B− leads to the audio amplifier. The intensity of the hum is not affected by turning the audio volume control.

2. 120-cycle hum bars (two cycles of change in brightness between the top and bottom of the raster), caused by hum voltage in the B-supply to the video amplifier. The hum bars in this case are present on the raster with or without a picture. If the hum is present on the B-supply to the rf-if amplifiers, but none on the video amplifier, the hum bars disappear when the TV picture is switched on, indicating that the hum is due to the B-supply filter circuit, and therefore is easily audible by the speaker, caused by hum voltage in the B-supply for the horizontal-afc section, the sync-divider section, the video amplifier, or the rf-if amplifier.

If the hum voltage is present only in the horizontal-afc or sync-divider section, the video amplifier will not be accompanied by hum bars. If the hum voltage is present in the rf-if or video amplifiers, the pulling is generally accompanied by hum bars.

When some or all of the above symptoms are present, it is advisable to check the B-supply filter circuit. A simple check can be made by connecting an external electrolytic capacitor temporarily across each of the suspected filter capacitors, in turn, and noting whether the symptoms disappear.

60-Cycle Hum Symptoms

It is well to remember that 60-cycle supply voltage is present only in the power transformer, the power rectifier plate circuit, and the heater transformers. The transformer and the rectifier plate circuit are rarely responsible for producing 60-cycle hum symptoms; a few exceptions are noted later. Visible symptoms of 60-cycle hum can almost always be traced to the heater circuits, or more specifically, to heater-cathode leakage in a tube. Such leakage permits the 60-cycle heater voltage to reach the television circuits via the cathode circuit of the tube.

Leakage between the heater and cathode of a tube may be caused by (a) faulty insulation between the two elements, or by (b) emission of electrons from heater to cathode, or vice versa, depending on the voltage difference and polarity of the two elements.

Leakage of any type between heater and cathode results in a flow of 60-cycle "hum" current through the cathode circuit during at least a portion of each 1/60th second. Such leakage current may or may not produce audible or visible hum symptoms, depending largely on the value of any resistance or 60-cycle impedance in the cathode circuit. Even a small amount of leakage current is likely to cause hum symptoms if there is a high value of resistance or 60-cycle impedance in the cathode circuit.

The above factors (the voltage difference, and polarity, between heater and cathode, and the value of resistance or 60-cycle impedance in the cathode circuit) account for the fact that a particular tube may cause hum trouble when it is used in one circuit of a receiver, but may operate without any sign of hum trouble when transferred to a different circuit.

Diode circuits, such as second detectors, dc restorers, horizontal-sync discriminators, and FM-sound discriminators, usually have a high value of resistance in the cathode circuit, and therefore are easily affected by heater-cathode leakage.

When the visible hum symptoms occur at 60 cycles, which generally indicates heater-cathode leakage, it is possible, in many receivers to temporarily short out the cathode resistor of each stage, in turn. The tube symptoms will disappear when the cathode resistor of the faulty tube is shorted out. This method is useful only where the normal operation of the stage is not seriously altered when the cathode resistor is short circuited. It is not advisable, in any case, to short out a cathode resistor permanently. The correct remedy, after isolating the faulty tube, is to install a new tube.

2. 60-cycle horizontal picture pulling, or one cycle of horizontal pulling between the top and bottom of the picture, as shown in Figures 2, 6 to 9.

When 60-cycle horizontal picture pulling occurs, without accompanying 60-cycle hum bars, as shown in Figures 2, 6 to 9, it is likely to be found in the horizontal-afc or oscillator sections, or in

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Fig. 4. Heater-cathode leakage in a tube in the rf or picture-if amplifier modulates any signal passing through these amplifiers, including "grain noise" or "snow" signals, as shown at left, or FM signals, as shown at right. Note that in each case the top portion of the kinescope is devoid of signal. The leakage current reduces the gain of the stage during the time corresponding to the black portion.

The same effect is evident at the center of Fig. 6, and the top and bottom of Fig. 7. Like many other troubles in electronic equipment, heater-cathode leakage can be intermittent, starting or stopping as the tube warms up. The particular tube used when these photographs were made had intermittent heater-cathode leakage.

Fig. 5. Some trouble as in Fig. 3, except that the heater-cathode leakage is 1000 ohms; note that the 60-cycle hum bars are more pronounced.

Fig. 6. In addition to 60-cycle change in picture brightness, heater-cathode leakage in the rf, if, or video amplifiers may also produce 60-cycle horizontal pulling in the picture. Both effects are evident in this example, which was produced by heater-cathode leakage in a tube in the picture-if amplifier (Refer to Fig. 7 and the note at the end of the caption for Fig. 9.).
the sync-separator section. Heater-cathode leakage in these sections may produce 60-cycle variation in horizontal-sync phasing, which appears as 60-cycle horizontal picture pulling. The pulling is present only on the picture, not on the raster, and it disappears when the TV signal is removed. The remedy is to try new tubes in these sections.

Again it is pointed out that the second detector, de restorer, and kinescope are part of the video-amplifier section—heater-cathode leakage in these tubes produces the same type of hum symptoms as those produced by the amplifier tubes in the video section.

Stationary and Moving Hum Symptoms

Hum bars and horizontal pulling (resulting from hum trouble in the receiver) may remain stationary or may move slowly or rapidly up or down on the picture. In either case, the effect depends on whether or not the ac line supplies for the receiver and the TV camera are in sync. There is no practical way to control this effect at the receiver.

"Hum Symptoms" Due to External Interference

External interfering signals with 60- or 120-cycle AM or FM modulation (such as generated by some types of diathermy equipment) may produce visible symptoms similar to internal hum. When the hum symptoms are produced by external interference, they are usually accompanied by a visible beat.

In the case of 60-cycle hum symptoms, a simple and positive check can be made by means of a power-cord plug. If the 60-cycle hum bars or horizontal pulling are caused by internal hum trouble, such as heater-cathode leakage, the hum symptoms will shift in position by about one-half of the height of the picture whenever the plug is reversed. Reversal of the plug has no effect on the position of "hum symptoms" resulting from external interference.

A Few Exceptions

1. Visible hum symptoms resulting from trouble in the B-filter circuit normally occur at 120 cycles, but the rare case where one-half of a full-wave rectifier circuit opens, any resulting hum symptoms occur at 60 cycles.

2. The filter capacitor at any one of the output taps on the B supply usually serves to prevent common coupling between the sections of the power transformer. Although this is true, there may be interaction between the sections. For example, an open filter capacitor in the B-feed to the vertical-output section may permit vertical-deflection voltage to set up 60-cycle hum symptoms in other sections. In general, if it is observed that signals in one section are modulating other sections, it is advisable to check the filter capacitors.

3. If 60-cycle hum bars remain present on the raster when the picture signal is killed, it generally indicates heater-cathode leakage in the video amplifier. In very rare cases, an exception may be found in the presence of a strong 60-cycle ac field from a power transformer located too close to the socket-end of the kinescope. An example of this rare effect is shown on K-3 in the RCA Television Pict-O-Guide* (Vol. 1).

Fig. 7. Same condition as in Fig. 6, except that the position of the hum symptoms has been shifted by reversing the power-cord plug.

There are many additional reasons for horizontal picture pulling. For further information on this subject, the reader is referred to anarticle by the author entitled "Horizontal Pulling," which appeared in the March and April 1951 issues of "Radio and Television News."

3. Combination of 60-cycle hum bars, and 60-cycle horizontal picture pulling, as shown in Figures 6, 2, 6, and 7.

The effects of hum voltage due to heater-cathode leakage in a tube in the rf, if, or video amplifiers may produce both 60-cycle hum bars and 60-cycle horizontal pulling. The presence of the 60-cycle hum bars indicates that the trouble is ahead of the kinescope (in the rf, if, or video amplifier). The procedure of applying the faulty tube is, therefore, the same as given previously under item 1 for "60-cycle hum bars."

Wires, components, and tube elements in the receiver may be shaken or vibrated by sound waves from the speaker, or by sound vibrations that are mechanical vibration of tube elements inside a tube produces slight variations in gain also.

Vibration of wires, components, or tube elements, with respect to each other or with respect to the chassis, produces slight variations in the capacitance and inductance of a circuit. Relative vibration of the elements in the tube produces slight variations in gain also.

Minor variations of capacitance and inductance, due to a normal amount of mechanical vibration, have no noticeable effects in any circuit except the rf oscillator, in which even the slightest changes in circuit constants produce considerable variation in the frequency of the.rf oscillator. Such variations in frequency, or frequency modulation, can result in an audible microphonic whistle.

Minor variations in gain, due to mechanical vibration of tube elements, have no noticeable effects except in the horizontal afe tube, which slight changes in gain can produce an appreciable amount of microphonic horizontal picture pulling.

The term "microphonic" is applied to these troubles because the electrical action is a result of mechanical vibration, as in a microphone.

Microphonic RF Oscillator

One of the most common types of microphonic trouble is a sustained whine or buzz heard in the headphones resulting from mechanical vibration in the r-f oscillator circuit. This trouble can be identified by the following symptoms:

1. The whistle is present only when a sound signal is being received. The signal may be from a TV, FM, or other station, with or without modulation.

2. The whistle is most likely to occur when the receiver is operated at moderate to high volume level. The whistle stops when the volume is reduced to a low level.

3. The trouble is most likely to occur on the high-band channels (7 to 13).

4. The whistle may cease during certain sound modulation, which breaks up the rhythm of the mechanical vibration.

5. The sound may be stopped temporarily by tapping the cabinet, the chassis, or the r-f oscillator tube. The tapping disturbs the rhythm of the mechanical vibration.

6. The whistle sometimes be stopped permanently or "semipermanently" by slightly moving or tilting the r-f oscillator tube in its socket.

7. The trouble does not occur in inter-carrier type receivers.

The complete cycle of operation of a microphonic trouble is as follows:

(a) Sound waves or transmitted vibrations from the speaker set up mechanical vibrations in one or more of the wires, components, or tube elements in the r-f oscillator circuit.

(b) This mechanical vibration produces slight variations in the capacitance and inductance of the oscillator circuit, which causes corresponding frequency variations, frequency modulation of the r-f oscillator signal.

(c) The frequency modulation of the r-f oscillator signal corresponds frequency modulation of the sound signal.

(d) The frequency modulation of the sound signal is detected in the sound discriminator, which produces audio-frequency output.

(e) The audio-frequency output of the discriminator is amplified in the audio amplifier, and produces motion of the speaker cone.

(f) The motion of the speaker cone produces sound waves and mechanical vibrations that tend to increase the amplitude of vibration in the r-f oscillator circuit.

(g) The above action is repeated, with reinforcement on each cycle, until a stabilized condition is attained. The result is an audible whistle that may last indefinitely, or occur intermittently, as an annoying background to the station's sound.

When the r-f oscillator signal is frequency modulated, it produces the same amount of FM in the picture signal, as in the sound signal, but there is rarely any visible evidence of this modulation.
in the picture. The FM response of the picture-if amplifier and second detector is much less than the FM response of the sound-if amplifier and discriminator due to the difference in the slope of the two response curves.

Inter-carrier receivers are not affected by a slight percentage of FM in the received signal, so that the signal may be processed and the interference eliminated by various filters. However, when the incoming FM exceeds a certain level, the interference will appear on the receiver, and the performance may be impaired.

If the receiver is operated at high volume level, a simple remedy in such locations is to remove the speaker from the cabinet, and mount it on a suitable baffle some distance from the receiver. Removal of the speaker decreases the amount of the sound waves inside the receiver, and virtually eliminates the possibility of microphonic trouble.

If a small speaker is used in the receiver, it may be difficult for the owner on the advantage of using a larger, external, pm speaker.

When an external speaker is used, it is advisable to check the audio output transformer in the receiver, and run two leads from the secondary of the transformer to the voice coil of the external speaker. Ordinarily, the voice coil is not involved in this purpose. The dc resistance of the voice coil in the new speaker should be approximately the same as that of the old speaker. The voice coil in the original speaker should be disconnected.

Sound Bars In The Picture

“Sound bars” are horizontal bars that vary in step with the modulation of the signal from the station. The music or dialogue varies with the frequency of the audio signal. At moments when the sound frequency is 300 cycles, there are five horizontal bars; when the sound frequency is 3000 cycles, there are 50 horizontal dark bars (one dark bar per 60 cycles).

The intensity of the bars varies with the strength of the audio signals. A clear voice or music signal is strongest, the bars also are strongest; at moments when there is no audio signal, the bars are absent.

There is general agreement to classify all variations of sound bars as “microphonic.” Actually, only a few types of sound bars are caused by microphonic action. Both microphonic and non-microphonic sound-bar troubles are described below.

1. Microphonic tube in the rf, picture-if, or video amplifiers.

A microphonic tube in the rf, picture-if, or video amplifier may produce sound bars in the picture when the receiver is operated at high volume level. The bars are not present at low volume level. These same symptoms also apply to the following trouble:

2. Inadequate or defective filtering in the plate or cathode supply circuits of the audio-output stage.

When the receiver is operated at high volume level, there are large audio-frequency variations of current in the output stage of the audio-output stage. These large current variations impose a varying strain on the B-supply. If the plate and cathode supplies are not adequately filtered, the current variations in the audio-output stage may produce an appreciable amplitude of audio-frequency ripple in the B-supply voltages. This ripple can affect the
operation of various sections of the receiver, producing audio-frequency variations in picture-signal gain, in width, in horizontal sync phasing, and other effects. The general effect is the appearance of sound bars in the picture. The bars are not present at low volume level.

When sound bars can be eliminated by reducing the volume level, it is necessary to determine whether the trouble is caused by microphonic action, or by inadequate filtering in the plate or cathode circuits of the audio-output stage. To determine which condition exists, open the voice-coil circuit of the speaker and advance the volume control. Opening of the voice-coil de-energizes the speaker and eliminates possibility of microphonic action. If the sound bars remain present, it indicates that there is inadequate filtering in the plate or cathode supply circuits of the audio-output stage. If the bars disappear when the voice coil is opened, it indicates that the trouble is probably due to a microphonic tube.

When this check is made, it is advisable to substitute a dummy-load resistor in place of the voice coil. The resistor should have approximately the same value as the dc resistance of the voice coil. The volume control should be set at the position where sound bars are visible, but below the overload point of the audio amplifier. After making this check, remove the dummy-load resistor and reconnect the voice-coil.

If the check shows that the sound bars are caused by microphonic action, check the rf, picture-if, and video tubes, either by lightly tapping each one to locate the faulty tube, or by substituting a new tube in each socket. Also try a new tube in the horizontal afc circuit.

If the check shows that the sound bars are caused by inadequate filtering, check the electrolytic filter capacitors in the plate and cathode circuits of the audio-output stage, and also the capacitors in the b-supply circuit, or try shunting an external electrolytic capacitor across each of the filters. If it is found that the original capacitors are good, and if the trouble cannot be corrected by the use of additional capacitors, it is advisable to find out whether the manufacturer has issued instructions on circuit changes to correct the trouble. All receivers of a particular model may exhibit this trouble when they are operated at high volume level, but actual complaints about the trouble may come from only a few commercial installations where the receivers are operated at high volume.

3. 4.5-Mc beat and herring-bone sound bars. Sound bars may appear in the picture if the 4.5-Mc beat signal between the sound-if and picture-if carrier gets through the video amplifier to the picture tube. The appearance of these bars is quite different from the appearance of the bars for the two previous troubles. The 4.5-Mc signal produces approximately 240 line dark vertical or slanting lines in the picture. The FM sound modulation in the 4.5-Mc signal produces horizontal herring-bone sound bars in the picture. The bars vary in step with voice and music. Unlike the two previous troubles, the intensity of the bars is not affected by adjustment of the volume control.

In inter-carrier receivers, the presence of a 4.5-Mc beat in the picture may be caused by incorrect alignment of the picture-if amplifier, or the 4.5-Mc transformer or trap(s) in the video amplifier.

In receivers that have a separate sound channel, the presence of a 4.5-Mc beat in the picture may be caused by incorrect tuning of the receiver, or by incorrect alignment of the sound-if traps in the picture-if amplifier, or the 4.5-Mc trap in the video amplifier.

4. Harmonic of sound-if signal. Harmonics of the sound-if signal are present in the output of the sound-if amplifier. If the frequency of one of these harmonics falls in the rf band of a particular channel, and if there is sufficient coupling between the output of the sound-if amplifier and the rf circuits of the receiver, the harmonic will produce a beat pattern in the picture. The beat frequency is equal to the difference in frequency between the rf picture carrier and the particular harmonic.

The FM sound modulation in the harmonic produces horizontal herring-bone sound bars in the beat pattern. The bars vary in step with the modulation. These bars are not affected by adjustment of the volume control.

There is a simple check to identify this type of trouble: Temporarily remove a tube from the sound-if amplifier. Removal of the tube kills the sound-if output and also the harmonics. If the beat pattern and sound bars disappear when the tube is removed, the trouble is caused by a harmonic of the sound-if signal getting into the rf circuits.

5. Microphonic tube in the horizontal afc circuit. Vibration of the elements in the horizontal afc circuit may cause variations in the gain of the tube and corresponding variations in horizontal sync phasing (horizontal picture pulling). If the vibrations are caused by sound waves, or by transmitted vibrations from the chassis, the horizontal pulling occurs at the sound frequency, and therefore has the appearance of sound bars. The amount of pulling varies with the intensity of the sound signal. This trouble is not present at low volume levels.

To become acquainted with this trouble, tap the horizontal afc tube lightly. Tapping may produce horizontal pulling or ripple in a portion of the picture. A certain amount of microphonic ripple is to be expected under this relatively severe check. Try several tubes in the afe socket, tapping each tube. Note that the microphonic action is less in some tubes than in others.

This microphonic action in the horizontal afe tube may be remedied by trying several new tubes and selecting the one that is least microphonic. If the afe tube socket is shock-mounted, arrange the leads (under the socket) to permit free-floating action. If these remedies are unsuccessful, the trouble probably is not caused by microphonic action. In this case, check for inadequate filtering, as described in item 2.

If a new tube is placed in the horizontal afe socket, check the horizontal-control action and make any necessary adjustments as specified by the receiver manufacturer.

Microphonic Troubles vs Intermittent-Contact Troubles

It is helpful to make a sharp distinction between microphonic troubles and intermittent-contact troubles.

The term "microphonic" should be restricted to cases where mechanical vibration of a component or tube produces an undesired electrical effect, but does not result in an intermittent contact, short circuit, or grounding.

Vibration of the elements in a 6SN7-GT tube in a horizontal afe circuit may produce microphonic horizontal picture pulling. The same tube, however, can be used in any other 6SN7-GT socket of the receiver without trouble. When normal vibration in a 6SN7-GT produces an intermittent contact or short circuit between two of the elements, the tube should not be used in any circuit.

Vibration is involved in both of these examples, but the first case is a microphonic trouble, and the second case is an intermittent-contact trouble. These examples show that there is a considerable difference between the two types of trouble.

In factory parlance, intermittent-contact trouble is known as "NWT," which means "noisy when tapped." Intermittent-contact trouble may show up under slight vibration, such as can be created by the speaker, or the trouble may show up only when the parts are vigorously vibrated by rapping the chassis with a tool, or by running the sound level so high that the parts vibrate.

Intermittent-contact troubles are caused by such things as (a) unsoldered joints, (b) cold-soldered joints, (c) stray strands of wire, (d) straw lumps of solder, (e) bare wires that are too close to other bare wires, or too close to the chassis, or too close to bare contacts, etc., etc.

The RCA test equipment recommended by the author of this series, in the earlier issues, has in several instances been superseded by later models. The following RCA instruments are currently recommended for TV servicing: WV-97A—Senior VoltOhmyst; WV-77A—Junior VoltOhmyst; WR-39C—Television Calibrator; WR-59B—Television Sweep Generator; WV-97A—Senior VoltOhmyst; WV-77A—Junior VoltOhmyst.
AUDIBLE HUM AND BUZZ*

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This article covers the localization of troubles in the receiver that cause audible hum and buzz, without attempting to accompany visible symptoms. In cases where audible hum is accompanied by visible hum symptoms, it is preferable to concentrate on the visible symptoms first.

The troubles that cause hum are different from the troubles that cause buzz. For trouble-shooting purposes, it is helpful to recognize the difference between these two sounds:

A hum is a "smooth" low-frequency sound.
A buzz is a "raspy" low-frequency sound.

Hum is produced by 60- or 120-cycle voltages that are sine-wave in shape, or that contain only low-frequency harmonics. When audible hum develops in a receiver that has been free from such trouble, it can usually be traced to heater-cathode leakage (60 cycles), or to trouble in triode-filament circuits.

Buzz is produced by square-wave vertical sync, vertical blanking, and low-frequency picture signals, or by saw-tooth vertical-deflection voltage. These square-wave and low-frequency voltages have a repetition rate of 60 cycles but contain numerous harmonics; the harmonics that are within the frequency range of the audio amplifier and loudspeaker contribute the raspy quality of the buzz. Heater-cathode leakage, however, can also cause a raspy buzz-like output.

Some Terms

When picture signals get into the sound, they produce a buzzing noise that is generally termed "picture buzz." Any buzz produced by picture signals can be identified easily because the tone and intensity of the buzz change on different televised scenes and on different "commercials." No other type of buzz has this identifying feature. For instance, buzz caused by vertical-deflection voltages (due to a desired coupling between the vertical-deflection section and the audio amplifier) remains unchanged in tone and intensity, regardless of changes in the picture.

The term "picture buzz" identifies the sound of the noise, but does not indicate whether the trouble is in the circuits that are getting into the sound. Picture buzz may be caused by a variety of troubles, including: Cross-modulation between the picture and sound carriers; coupling between the kinescope metal cone (or inner coating on glass-envelope type) and the audio input; coupling between the output of the rf or if amplifier and the input of the audio amplifier; 100 per cent modulation dips at the transmitter (which affect inter-carrier sets), and other reasons.

The terms "picture signals" and "audio signals" are used interchangeably in two different ways. Occasionally they are used to mean only those signals that represent the dark and light areas in the picture, but in most cases they are used to mean the composite signal, which includes picture, sync, and blanking. The latter meaning is always implied in referring to a "picture buzz," because, in a receiver, the picture signals are always accompanied by the blanking and sync signals only when the injected low-frequency composite signal that produces "picture buzz.

Only the low-frequency components of the composite picture, blanking, and sync signals can get through the audio system and become audible. The audio system in TV receivers may cut off at approximately 60-cycle vertical blanking and sync signals, which represent large dark and light areas in the picture.

The term "sync buzz" is often used instead of "picture buzz," but the term "sync buzz" should be restricted to the rare cases where vertical-sync pulses from the sync separator are getting into the sound.

Audio Hum

In cases where there is hum (not buzz) from the speaker, and the hum is present on all channels, including blank ones, first determine whether the intensity of the hum varies with adjustment of the volume control. If the hum does not vary with adjustment of the volume control, the trouble is generally in circuits AFTER the control.

If the intensity of the hum can be reduced to the vanishing point by turning the control counter-clockwise, the trouble is generally in circuits AHEAD of the control. (One exception may be mentioned here.)

In cases where the intensity of the hum does vary with adjustment of the volume control, try a new tube in the sound-discriminator circuit. If the hum stops, it can be assumed that the original tube had heater-cathode leakage, which introduces 60-cycle heater voltage into the audio-input circuits.

It should be remembered that the discriminator tube and the discriminator-output circuits are a part of the audio-input circuit, and are subject to the same picture troubles, such as heater-cathode leakage, and electrostatic pickup of hum, buzz, and other extraneous signals. In cases where the intensity of the hum does not vary with adjustment of the volume control, the following "process of elimination" may be used:

1. Try a new tube in each stage of the audio amplifier. If the hum stops, the trouble was probably due to heater-cathode leakage in the original tube.
2. If new tubes do not eliminate the hum, remove the audio-output tube: If the hum is still present, there is something radically wrong in the audio-output transformer or speaker circuit, which should be checked in order to locate the fault.
3. If the hum stops when the audio-output tube is removed, then the tube back in its socket, and remove the first-audio tube.
4. If the hum is still present with the first-audio tube removed, it indicates that there is excessive heater-cathode leakage (60 cycles), or to trouble in vertical-sync, vertical blanking, and sync signals. It is the effect of the composite signals that produces "picture buzz.

Modulation Hum

The term "modulation hum" is used to distinguish this trouble from "audio hum." There is a great difference between the two. Audio hum is present at all times, regardless of volume settings being received. Modulation hum is present only when a station is being received.

Modulation hum is caused by the presence of undesired hum voltages in the audio signal (in addition to the rf oscillator and converter). The hum voltages modulate the rf or if signal. The modulation is AM, except in cases where the hum trouble occurs in the rf-oscillator circuit and produces both AM and FM.

Modulation hum in TV receivers is usually caused by:

(a) Excessive hum-voltage ripple on the plate, grid, or screen supplies to any tube through which the rf or if signal passes.
(b) Excessive hum-voltage ripple on the plate, grid, or screen supplies to any tube through which the rf or if signal passes.

If there is hum trouble in any tube through which both the sound and picture rf or if carriers pass, the trouble may be present on the picture in the sound, because the action of the sound-if limiter and discriminator tend to wipe out amplitude modulation on the sound-if carrier.

Modulation-hum trouble may not affect all of the TV stations. For instance, if the trouble is caused by heater-cathode leakage in an rf or if tube, and if the particular tube is almost cut off by age action on a strong local station, the hum voltage will not modulate the signal of this particular station.

In AM receivers, modulation hum can be easily identified by its tuning action. The hum becomes audible when the receiver is tuned to the station, and it disappears when the set is tuned away from the station. It is for this reason that modulation hum in AM receivers is often described as "tunable hum." The tunable action of AM modulation hum is entirely different in FM receivers, and on the FM sound in TV. 

*In receivers having a transformer-type power supply.
receivers. Because the limiter and discriminator tend to eliminate any amplitude modulation that is present and increase the sensitivity of AM modulation hum decreases when the receiver is correctly tuned to the station. Correct tuning is the point where the frequency of the sound-if signal is the same as the center frequency of the discriminator. The intensity of modulation hum in inter-carrier receivers or IF stages which are tuned slightly above or below the correct point. This tunable action of modulation hum is evident only on TV receivers that have a separate channel for the sound-if signal. In inter-carrier receivers, the sound if (4.5 Mc) is fixed in frequency and it cannot be adjusted by turning the tuning control of the receiver. Hence, in inter-carrier receivers, there is no tunable action in cases of modulation hum.

The cause of modulation hum in TV receivers may be determined by:
(a) Trying new tubes in all stages through which the rf or if sound signals pass. (Only those stages that have a resistance of 50 ohms importance in the cathode circuit are likely to show any effect from heater-cathode leakage).
(b) Using a voltage-calibrated oscilloscope (such as the RCA WO-56A) to check the wave-form of the line-pickup ripple on the plate, screen, and grid supplies for the rf and if amplifiers.
(c) Checking the alignment of the sound-if amplifier and the sound discriminator by using a signal generator equipment (such as the RCA WR-59B Television Sweep Generator, and the WR-39C Television Calibrator). Incorrect alignment greatly reduces the ability of the limiter and discriminator to wipe out amplitude-modulation hum and hum.
(d) In inter-carrier receivers, it is important to align the sound-if amplifier and discriminator exactly at 4.5 Mc in order to obtain the greatest reduction of AM hum and buzz. The WR-39C Television Calibrator aligns the limiter, which may appear on the other signal, and provides the greatest possible accuracy for this work.

In the case where hum is present on only one station, it is always advisable to check another receiver to determine whether the hum is present on the station's sound carrier.

For general background information, it is helpful to consider another cause of modulation hum which occurs, under certain conditions, in AM radio receivers (especially in ac/dc sets) that have a small loop or "hank" antenna. In many locations, considerable signal energy one from one or more of the local transmitters is picked up by the power line. The strength of such signals at the receiver may be affected by the action of the power rectifier, positive half-cycles of the power-supply voltage, the rectifier and first filter capacitor form an effective rf short circuit across the line; on negative half-cycles, the rectifier is effectively an open circuit. This action may produce a variation, at the power-line frequency, in the strength of the line-pickup signal.

If some of this hum-modulated signal is coupled into the antenna, it will be amplified on the local circuit and will feed into the sound circuit. The hum-modulated signal on the local circuit will not interfere with the picture signal. Therefore, the intensifier of the picture amplifier is used to amplify the video signals and the 4.5-Mc sound-if signals. Cross modulation can occur in any of these stages, as is described in the previous paragraphs.

Cross-modulation buzz can be demonstrated on strong stations, by momentarily short-circuiting the audio amplifier, and then turning the power amplifier back on. The loud hum and buzz will immediately fall off when the power amplifier is turned back on. This is caused by the crossover action of the audio amplifier.

Occasionally, in the process of making adjustments at the station, the carrier may unintentionally be modulated down to zero amplitude for a short period of time. Therefore, the audio output of the second detector, which is fairly constant at one time, is null which will produce a buzz as described in this article.

Cross-Modulation Buzz

When two rf or if signals of different frequencies are amplified in the same stage, there is a possibility that the modulation on one signal may cause a beat frequency between the picture and sound signals. The possibility of cross modulation in these receivers is greatest when the two signals are close in frequency and when the audio output of one signal is amplified in the 4.5-Mc sound-if amplifier. Cross modulation can occur in any of these stages, as is described in the previous paragraphs.

Zero Picture-Signal Buzz

In inter-carrier receivers, the sound-if signal of 4.5 Mc is amplified at the second-detector by the difference-frequency beat between the picture- and sound-if carriers. The frequency of this beat depends solely on the difference in frequency between the rf picture and sound carriers. The specified standard separation between the picture and sound carriers is 4.5 Mc, hence the beat is 4.5 Mc.

The 4.5-Mc beat, which has sound frequency modulation, is amplified in the 4.5-Mc sound-if amplifier and fed into the sound discriminator. The audio output of the discriminator is amplified by the audio amplifier and fed into the speaker. Obviously, if there is no 4.5-Mc beat, there will be no sound output.

In order to obtain a 4.5-Mc beat signal at the output of the second detector, it is necessary that both the sound and the picture signals be present in the input to the second detector. If either the picture or sound signal is missing for any reason, there will not be a 4.5-Mc beat, and, consequently, there will be no sound output from the speaker. If the station shuts off its picture carrier so that there is no picture signal at the receiver, there will also be an absence of sound. Described in this manner, the station is transmitting its normal frequency-modulated sound carrier.

Suppose that the station transmits an unmodulated sound carrier, but that it reduces the picture carrier to zero amplitude for a short period every 1,600th of a second. If the 4.5-Mc beat is turned on when the picture carrier is cut off, there can be no 4.5-Mc beat and no sound output from the speaker. The presence of 60-cycle buzz in the speaker will not affect the sound because the 60-cycle buzz in the speaker will not affect the sound. Therefore, in this case, the sound is transmitted by a picture carrier, and the picture signal is zero-amplitude, or if the bias is incorrect, or if the tube has a restricted linear operating range.

In inter-carrier receivers, the entire amplifier is used to amplify both the picture-if and sound-if signals. Also, in some inter-carrier receivers, one or two stages in the audio-frequency amplifier are used to amplify both the video signals and the 4.5-Mc sound-if signals. Cross modulation can occur in any of these stages, as is given in the previous paragraphs.
tubes in the video amplifier, check the voltages on the video tubes, and try changing the bias slightly on each stage. This will reveal which stage in bias may affect the video signals.

To avoid unnecessary waste of time on cases of cross modulation, it is always a good practice to find out whether in receivers where the picture is distorted, whether the manufacturer has recommended any changes to correct the trouble.

High-Voltage Buzz

Due to the regulation characteristics of the high-voltage supply, there is considerable low-frequency variation in the high-voltage for the picture tube. The voltage is highest at times when the beam current at cut off by long-duration black signals, such as vertical blanking. The voltage is lowest at times when the average beam current is highest, which occurs during large, wide, white areas in the picture. Also, variations in high voltage are repeated at the field frequency of 60 cycles. If there is stray capacitive coupling, even a few microfarads across the high-voltage circuit and the audio-input circuits, the variations in high voltage are likely to be transmitted to the output from the speaker. The intensity and tone of the buzz change on different televised scenes and on components close to the chassis.

This type of buzz, which will be referred to as high-voltage buzz, can be identified as follows:

(a) The intensity of the buzz decreases when the brightness control is turned down.

(b) The intensity of the buzz decreases when the contrast control is turned down.

(c) The buzz ceases when the high-voltage lead is disconnected from the picture tube, or when the socket is removed from the rear of the picture tube.

High-voltage buzz is generally found only where the audio-input circuits, such as the sound discriminator, volume-control, or first-audio tube circuit, are within a few inches of the high-voltage-electrode connector, and where there is no electrostatic shielding between this electrode and the audio circuits. This is because by shielding all of the audio circuits are underneath the chassis, the chassis acts as an electrostatic shield. In receivers with glass-type picture tubes having an outer conductive coating, the outer coating acts as an electrostatic shield. In receivers with vacuum tubes having an outer conductive coating, the outer coating acts as an electrostatic shield. Provided that the connection to the chassis is made to a different potential from the chassis, and that the equipment is not operated at high frequency level, or is used in a noisy room, the sound from a buzzing transformer is generally masked by the stronger sound from the speaker.

In cases where there is a snapping or cracking sound of high-voltage arc-over, but where the arc-over cannot be seen, it is advisable to install a new high-voltage filter capacitor.

Buzzing Power Transformers

Buzzing transformers are produced mainly by buzzes from the medium frequency of 15750 cycles, which is beyond the hearing range of the majority of men, but may be annoying audible to women and young persons.

Mechanical vibration in an audio-output transformer produces tin sounds of voice and music, or "singing." Any sound from the horizontal frequency of 15750 cycles, is generally masked by the stronger sound from the speaker.

On rare occasions, sounds may come from mechanical failure of the transformer (which has not been properly impregnated, and in which the coil has been wound too loosely) if the buzz is produced by hitting any sharp points on wires and solder, and by using high-voltage plastic insulating material wherever necessary.

Snapping, Crackling, or Sizzling Sounds

Buzzing Transformers

In tracking down the cause for audible hum and buzz, first determine whether the sound is coming from the speaker or if it is being created by mechanical vibration or buzz in a transformer.

The alternating or pulsating currents that flow through the coils of a transformer set up fluctuating magnetic fields that tend to induce eddy currents in the laminations and coils vibrate in step with the changes in current. Precautions are taken in the design of transformers to prevent mechanical vibration. The laminations are tightly clamped together and are usually dipped in varnish to form a non-conducting film; the wires are thoroughly impregnated in wax or varnish to form a non-vibrating unit; the coil assembly is tightly bound to the core; and the core-and-coil assembly may be "potted" or buried in an insulating compound which further restricts vibration. Yet, in spite of these measures, a small percentage of transformers develop an objectionable amount of buzz.

Experience has shown that the vertical-output transformer is the chief source of buzz. The vertical-oscillator transformer may buzz, and there is a possibility of buzz in the vertical section of the deflection circuits.

An important point to remember in connection with buzz in any vertical transformer, is that the tone of the buzz can be altered by choosing the proper vertical circuit, or by adjusting the vertical hold control. Stated oppositely, if the tone of a transformer is not steady, and the vertical hold control is turned, the buzz originates in a transformer in the vertical section of the receiver.

The power transformer is probably the second chief offender in producing buzz. Any power transformer is likely to buzz if it is greatly overloaded by a short circuit across a portion of a winding. A short circuit, however, usually produces other and more important symptoms.

Vibration of the core or coils in a horizontal-output transformer may produce a high-pitched whistle. This type of buzz may be produced by components close to the chassis, and by connecting the tinfoil to the chassis, this buzzing may be eliminated.

When ozone is produced by the tube of the transformer, it is produced by high-frequency currents passing through the air, and the resulting sound may be heard at a considerable distance.

Almost all complaints involving buzzing transformers come from installations where the receiver is operated at low volume level in a quiet room. When the receiver is operated at high volume level, or is used in a noisy room, the sound from a buzzing transformer is likely to be unnoticed. The intensity of the sound is influenced by the distance between the cabinet and the room, which may deaden or reinforce the sound. Listening checks for buzzing transformers should be made with the receiver turned off under normal listening conditions. The same precaution applies when investigating complaints of low-level hum or buzz in the receiver. When the volume is turned up, the buzzing may become more noticeable.

To prevent possible confusion when checking for buzzing transformers, it is advisable to kill the audio output of the receiver, either by removing the drive transformer, or by short-circuiting the primary of the audio-output transformer.

Buzzing Power Transformers

If the buzz seems to be coming from the power transformer, temporarily remove or disconnect the
power rectifier, thus eliminating all other possible sources of hum or buzz in the receiver. The heater lead is generally a length of fine wire and can be left alone. When the heater is turned on but the buzzer continues to sound, it indicates that the power transformer is buzzing, try tightening the bolts that clamp the laminations together. Don't draw up too tightly on the bolts, because they have an annoying habit of shearing off.

If tightening of the bolts does not reduce the buzz sufficiently, disconnect the power cord, remove one or both of the end bells (covers), and check to see if the coil assembly is tightly wedged on the core. The transformer may have wedge-shaped pieces of impregnated hardwood or fiber inserted between the core and the inside of the end bells. If this is the case, move the wedges tightly into position; drive in new wedges if necessary.

Look for loose laminations on either end of the stack. In some transformers the laminations are bonded to a solid block by means of varnish. If loose laminations have been added, in order to obtain the required output, they may be contributing to the buzz. Apply a coat of varnish to the loose laminations and, while still wet, replace them in the transformer. If the Buzz stops, tighten the bolts, and check for buzz. If the Buzz has been reduced sufficiently, replace the receptacle, if it is loose, and check for Buzz. If the Buzz is objectionable, it may be necessary to replace the transformer.

A quick check for Buzz in the power transformer can be made by listening to the Buzz in the vertical-output tube. If Buzz stops, the Buzz is objectionable, it may be necessary to replace the transformer. If Buzz does not stop, the Buzz is objectionable, it may be necessary to replace the transformer. If Buzz does not stop, the Buzz is objectionable, it may be necessary to replace the transformer.

Buzzing Vertical Transformer

When there is reason to believe that buzz is caused by a transformer in the vertical circuits, kill the audio output of the receiver and rotate the sets. If Buzz is still heard in the vertical section of the Buzz, it is a definite sign that the Buzz is coming from a transformer in the vertical section. In this case, temporarily remove the Buzz in the vertical-output tube. If Buzz stops, the Buzz is objectionable, it may be necessary to replace the transformer. If Buzz does not stop, the Buzz is objectionable, it may be necessary to replace the transformer.

Buzz in the vertical-output transformer may be caused by a partial short circuit in the transformer windings or in the circuit. The most prominent symptom in this case, is vertical-deflection trouble.

Remedies for a buzzing vertical transformer are the same as for power transformers, namely: Tighten the transformer, check for Buzz, and finally, if Buzz does not stop, replace the transformer. The Buzz in the vertical-output transformer is objectionable, it may be necessary to replace the transformer. If Buzz does not stop, the Buzz is objectionable, it may be necessary to replace the transformer.

Buzz in a vertical-output transformer may be caused by a partial short circuit in the transformer windings or in the circuit. The Buzz in the vertical-output transformer is objectionable, it may be necessary to replace the transformer.

Shorted Turns May Cause Buzz.

Many technicians do not fully realize that an ohmmeter will NOT check for a short circuit on a transformer windings or in the circuit. The Buzz in the vertical-output transformer may be caused by a partial short circuit in the transformer windings or in the circuit. The Buzz in the vertical-output transformer may be caused by a partial short circuit in the transformer windings or in the circuit. The Buzz in the vertical-output transformer may be caused by a partial short circuit in the transformer windings or in the circuit.

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Buzzing Vertical Transformer

When there is reason to believe that buzz is caused by a transformer in the vertical circuits, kill the audio output of the receiver and rotate the sets. If Buzz is still heard in the vertical section of the Buzz, it is a definite sign that the Buzz is coming from a transformer in the vertical section. In this case, temporarily remove the Buzz in the vertical-output tube. If Buzz stops, the Buzz is objectionable, it may be necessary to replace the transformer. If Buzz does not stop, the Buzz is objectionable, it may be necessary to replace the transformer.

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HORIZONTAL PULLING*

By John R. Meagher
Television Specialist. RCA Renewal Sales

Part 1. Although horizontal pulling is a common trouble in television receivers, there is practically no information available on the subject. This article is designed to meet the need for authoritative data on its causes and remedies.

To simplify a rather complex story, numerous kinescope photographs are used to show the effects of horizontal pulling, as well as other visible symptoms, resulting from a variety of troubles. In many of these examples, the pulling effects are incidental. For this reason, the photographs and their explanatory captions are helpful in diagnosing other symptoms, in addition to horizontal pulling.

A Few Terms
When set owners complain of horizontal pulling, they may describe the symptoms by saying that telephone poles, doors, and windows in the TV picture appear bent, bowed over, curved, snaky, etc. Most technicians use the terms "horizontal pulling" and "horizontal bending" more or less interchangeably, usually reserving the latter for mild cases of pulling. The terms "wavering" and "weaving" are generally applied in cases where the extent of pulling varies.

The writer uses the terms "raster pulling" and "picture pulling," because there is a real difference between the two effects, even though both produce the same outward symptoms in the picture. The troubles that cause raster pulling are usually entirely different from the troubles that cause picture pulling, as we shall see.

Slight Bending at Top
One of the most common types of picture pulling is a slight bending, toward the left or right, at the top of the picture. The bending can usually be varied, or even straightened out, by adjustment of the horizontal hold control or the contrast control or, in some receivers, by the a.g.c. threshold control or switch. Occasionally, the bending at the top of the picture may shift, or "lag-wave," back and forth from left to right. In cases where slight bending or flag-waving at the top of the picture is normal and common in a particular model of receiver, it is often a waste of time for the technician to check for defective components. The bending, in such cases, may be more of a design problem than a service problem.

Many technicians have wondered why the top of the picture is most susceptible to horizontal pulling (or actual tearing in receivers without horizontal a.f.c.). One reason is that the horizontal sync action is most likely to be unstable immediately following the disturbance of vertical sync. The top of the picture follows after vertical sync, hence any instability of this type that may exist in the receiver will show up at the top of the picture. Another possible cause in some receivers is that the surge in the vertical oscillator, following vertical flyback, may be coupled into the horizontal sync circuit, producing a disturbance in horizontal sync phasing at the top of the picture. A simple check for the presence of this trouble is described later.

Two Types of Pulling
For troubleshooting purposes, it is helpful to recognize that there are two basic types of horizontal pulling:

1. "Raster pulling," where the pulling or bending is present on the raster, without a picture. Naturally, any pulling or bending on the raster is equally evident on the picture. One example of raster pulling is shown in Fig. 1. Possible causes include:

   (a) Troubles in "B" supply filtering.
   (b) Troubles in the horizontal deflection section.
   (c) Troubles in the deflection yoke.
   (d) Undesired magnetic fields near the picture tube.

2. "Picture pulling," where the pulling or bending is present on the picture, but not on the raster. Examples of picture pulling are shown in all of the photos except Fig. 1. Picture pulling is a direct result of variation in horizontal sync phasing, as described later. Possible

*Courtesy Radio & Television News. Reprinted from the March & April, 1951, issues (Vol. 45, No. 3 & 4).

Fig. 1. Two cycles of bending between top and bottom of raster or 120 cycle change in amplitude of horizontal deflection as caused by open condensers in the "B+" filter circuit. The bending is present on the raster either with or without a picture.

Fig. 2. Slight horizontal pulling, as evidenced by bending of the left and right hand sides of the box around "WFIL-TV," caused by an undesired magnetic field near the picture tube. The pulling, which is present on the raster with or without the picture, may be horizontal, vertical, or both, depending on the location of the field. If the field is due to a magnetized portion of the shell of a metal-type picture tube, it may be detected by turning the tube, thus shifting direction of pulling.

Fig. 3. Slight horizontal pulling at top of picture, accompanied by dark vertical bars at left, caused by open filter condensers in the "B+" feed to the horizontal deflection circuit. Horizontal blanking and sync signals are intentionally brought into view in this photo to show that there is no variation in width of raster but that there is variation in horizontal sync phasing at top of picture where it may be noted that shortstop and edge of picture are bent toward the left. Vertical hold control was adjusted to bring vertical blanking and sync into view in order to show that the horizontal bending exists only at the top of the picture. Also see Fig. 5.
causes for picture pulling include:

(a) Poor low-frequency response in the r.f., i.f., or video amplifiers.
(b) Undesired limiting action in the video amplifier due to trouble in the amplifier or to excessive signal input.
(c) 60-cycle modulation of the horizontal sync pulses, due to hum or a.c. feed-back in the r.f., i.f., or video amplifiers, the sync separator, or the horizontal a.f.c. circuit.
(d) Excessive or insufficient sync signal input to the sync separator or troubles in the sync separator.
(e) Extraneous signals coupled by any means into the horizontal a.f.c. circuit.
(f) Electrical hunting action in the horizontal a.f.c. circuit.
(g) Extremely weak signals, interference, some reflection conditions, and other reasons.

It is desirable to consider the subject of raster pulling first.

Raster Pulling

Under normal conditions, all of the horizontal scanning lines in the raster have exactly the same length and the left- and right-hand edges of the raster are straight and parallel. If, however, there is any variation in the amplitude of horizontal deflection, some of the scanning lines become longer or shorter than others, resulting in the appearance of horizontal pulling or bending at the edges of the raster. One example of raster pulling is shown in Fig. 1, where 120 cycle ripple in the "B" supply causes the scanning lines to be bent. Another example of raster pulling is shown in Fig. 5, where horizontal sync is present and the raster is straight, indicating pulling is not present in raster itself.

Fig. 5. Detailed section of the photo of Fig. 3. Note that the leading edge of horizontal sync, which should be parallel to the edge of raster, is not parallel (at the upper portion) thereby indicating a variation in horizontal sync phasing. Edge of raster is substantially bent, indicating pulling is not present in raster itself.

When the cause for horizontal pulling is not immediately evident, it is a good practice to inspect the horizontal blanking and sync signals at the right-hand edge of the picture. These signals may be brought into view by moving the picture centering to the left, and by reducing the contrast and increasing the brightness to make the sync appear dark gray, as shown in Figs. 3 and 4. It may be necessary to adjust the horizontal hold control so that a sufficient portion of horizontal sync appears in view. In some receivers, it may be necessary to adjust the a.g.c. threshold control to secure sufficient reduction in contrast, and temporarily short out a resistor in the brightness-control circuit for sufficient increase in brightness.

By inspection of the horizontal blanking and sync signals, as in the examples shown in Figs. 3 and 5, we can immediately determine two facts:

1. The right-hand edge of the raster is not bent, but is straight. This is a positive indication that the particular pulling is not present on the raster.
2. The leading edge of horizontal sync is definitely pulled or bent with respect to the edge of the raster. Stated differently, there is a variation in the spacing (phasing) between the leading edge of horizontal sync and the edge of the raster. The spacing, or phasing, at the top portion of the picture is wider than at other portions. The trouble, therefore, is picture pulling due to variation in horizontal sync phasing.

Regardless of any trouble in the receiver, the right-hand edge of the picture is always parallel to the leading edge of horizontal sync. The spacing between the edge of the picture and the leading edge of horizontal sync represents the "front porch" between the picture signals and the horizontal sync.

In Figs. 4 and 6, it may be seen that there is a variation in the spacing, or phasing, between the leading edge of horizontal sync and the edge of the raster. For instance, in Fig. 4, the spacing is wider at the top and narrower at the bottom. In both Fig. 4 and Fig. 6, the edge of the raster is actually straight, although this fact is not clearly apparent because the particular trouble has darkened some portions of the picture. In working on a set, it is usually a simple matter to bring the entire edge of the raster into view by adjusting the contrast and brightness controls.

Up to this point, we have shown how any case of horizontal pulling may be quickly and easily classified into one of the two basic types—
raster pulling or picture pulling. We have also discussed simple means for localizing the troubles that cause raster pulling. We will now consider the steps that may be necessary in localizing troubles responsible for picture pulling.

The composite (picture, blanking, and sync) signal from the TV station passes through the r.f., i.f., and video amplifiers, and appears on the picture tube. With normal adjustment of contrast, the blanking and sync signals are blanked out, or blacked out, and are not visible on the picture tube. They may, however, easily be brought into sight and are then extremely useful in diagnosing certain troubles.

The composite signal is picked off at some point in the receiving circuits, usually in the video amplifier, and is fed into a sync separator. Under normal conditions, the sync signals are about 33 1/2% higher in voltage than the blanking signals which, in turn, are slightly higher in amplitude than the darkest picture signals. On the basis of the difference in sync amplitude, the sync separator is designed to pass the high-amplitude sync and (by limiting and clipping action) to remove the blanking and picture signals. The output of the sync separator should consist of sync pulses only with no trace of and no effect from the blanking and picture signals.

The horizontal sync pulses that are delivered from the sync separator to the horizontal a.f.c. circuit should have uniform amplitude, uniform spacing (phasing), and uniform duration. The horizontal sync pulses that occur during the vertical equalizing and sync interval have different duration but normally this difference is wiped out through differentiating action.

Any trouble in the r.f., i.f., or video amplifier that acts to reduce the amplitude of sync, bringing it closer to the blanking and picture level, will make it difficult or impossible for the sync separator to function properly and may result in horizontal picture pulling or complete loss of sync.

In this connection, there are two principal troubles to watch for in the r.f., i.f., and video amplifiers:

1. Poor low-frequency response. The sync pulses represent relatively low-frequency signals. Inadequate low-frequency response in the r.f., i.f., or video amplifiers can reduce the amplitude of sync in comparison with the higher-frequency picture signals. The usual reason for poor low-frequency response in the r.f. and i.f. amplifiers is incorrect alignment of the picture carrier too low on the slope of the response curve. An example of picture pulling caused by incorrect alignment is shown in Fig. 7.

2. Undesired limiting action in the video amplifier can seriously reduce the sync amplitude. The usual reasons for undesired limiting in the video amplifier are:

(a) Excessive amplitude of signal input to the video amplifier, resulting from trouble in the a.g.c. circuit, is satisfactory, check the tubes, i.f. amplifier, using a good sweep generator and a crystal-calibrated marker oscillator. If the alignment is satisfactory, check the a.g.c. threshold control, as shown in the illustration, Fig. 8.

(b) Incorrect plate, screen, or bias voltages due to circuit, components or tube trouble in the video amplifier or in the power supply. An example of limiting and horizontal pulling caused by low plate voltage on a video amplifier is shown in Fig. 9.

(c) Defective or worn-out tubes in the video amplifier.

Part 2. Additional causes of and remedies for horizontal pulling.

Fortunately for the television technician, any appreciable loss of low-frequency response in the r.f., i.f., and video amplifiers and any appreciable undesired limiting action in the video amplifier can be detected very quickly by visually checking the relative intensity (blackness of the vertical sync, vertical blanking, and picture signals, as they appear on the picture tube. To observe these signals, it is necessary to adjust the vertical hold control so that the picture rolls slowly downward out of vertical sync. It is necessary also to adjust contrast and brightness to make the vertical blanking and sync signals visible, as shown in Fig. 11, which represents approximately the correct relative darkness of these signals. For inspection purposes, it is preferable to increase the brightness slightly or decrease the contrast slightly in order to make the vertical sync appear as a dark grey, instead of the dead black shown in Fig. 11. We suggest that the reader carefully study the photographs and captions in Figs. 11, 12, 13 and 14.

In all cases of horizontal picture pulling, it is a worthwhile practice to check the relative intensity of sync, as shown in Fig. 11. If the inspection reveals that the low-frequency response is poor, check the alignment of the r.f. and picture i.f. amplifier, using a good sweep generator and a crystal-calibrated marker oscillator. If the alignment is satisfactory, check the tubes, components, and voltages in the video amplifier. If the inspection reveals limiting action, check the video amplifier and the a.g.c. output voltages.

If the relative intensity of the sync, blanking, and picture signals appears normal, it may be assumed that the picture pulling is not caused by trouble in the r.f., i.f., or video...
amplifiers. Attention should then be
concentrated on the sync separator and the horizontal a.f.c. circuit.

Localizing the Cause

The writer suggests a simple check that is occasionally helpful in
isolating the cause for picture pulling. Briefly, this check consists of
removing horizontal sync input from the horizontal a.f.c. circuit, free-wheeling the horizontal oscil-
lator to obtain a momentarily sta-

tionary picture, and noting whether the pulling is still present on the
picture. The check is helpful in
showing whether the trouble is in the
a.f.c. circuit or ahead of it. The
procedure is as follows:

Make a mental note of the posi-
tion and amount of horizontal pull-
ing. Temporarily disconnect the
condenser that connects horizontal
sync pulses (from the sync separa-
tor) into the horizontal a.f.c. circuit.
Disconnecting the condenser will
throw the horizontal oscillator com-
pletely out of sync. With the hori-

tzontal hold control set at its mid-
position, turn the main frequency
adjustment of the horizontal oscil-
lator to bring the oscillator to the
correct frequency, as indicated by
the momentary appearance of a
complete picture. Then carefully
adjust the horizontal hold control in
an attempt to keep the picture from
rolling horizontally for at least a
second, or just long enough to
inspect the picture and to determine
whether the picture pulling has dis-
appeared. If (with horizontal sync
removed) the picture pulling is still
present, the cause of the pulling is
probably in the horizontal a.f.c.
circuit. But if (with horizontal sync
removed) the pulling is not present on
the picture it indicates that the
trouble is ahead of the horizontal
a.f.c. circuit.

Occasionally extraneous signals
from an adjacent video amplifier,

audio amplifier, or other source may
be coupled into the horizontal a.f.c.
circuit. This possibility should be
considered in cases where the pre-
vious check indicates that the cause
for picture pulling is in the hori-

zontal a.f.c. circuit.

In Part 1 of this article, mention
was made of the possibility that
trouble is ahead of the horizontal
a.f.c. circuit.

A general method of determining
whether the vertical oscillator and
deflection circuits are in any way
responsible for horizontal pulling is
to remove the vertical oscillator and
vertical integrating network and

free-wheel the vertical oscillator, by
careful adjustment of the vertical
hold control, to keep the picture
from rolling vertically. If the hori-
zontal pulling disappears when the
condenser is opened, it may indicate
that additional isolation is required
between the vertical oscillator and
the horizontal sync input circuit.

In many receivers, the amplitude
of sync input to the sync separator
is rather critical; either too much or
too little sync input may cause
picture pulling. In cases where all
components have been checked and
appear to be normal and the cause
for pulling cannot be localized by
the methods suggested, it may be
advisable to try changing the level of
the sync input to the sync separa-
tor. If the sync signal for the sync
separator is taken from across a
resistor in the video amplifier, it
may be feasible to alter the value of
the resistor or temporarily substi-
tute a carbon potentiometer to
determine the optimum value.

The tubes, voltages, and load re-
sistors in the sync separator are
usually critical with respect to pic-
ture pulling. Occasionally, it may be
helpful experimentally to alter the
value of a plate-load resistor in the
sync separator. The writer offers
these comments reluctantly, be-
cause he is definitely not in favor of
the practice of altering the value of
one component to compensate for a
defect in another component that
has escaped detection.

When picture pulling is common
in all receivers of a particular model,
the logical procedure is to find out
whether the manufacturer has issued

Fig. 11. Portion of vertical blanking and sync signals for single field. In making
this picture and those of Figs. 12, 13, and 14, the contrast was reduced and
brightness increased in order to "unblank" the blanking lines. Camera shutter
was opened for only 1/60th second, which is time required for electron beam in
picture tube to trace a single field of approximately 262 lines, consequently every
other horizontal scanning line is absent in this photo, which otherwise repre-
sents normal signal conditions. As clearly shown, the blanking is slightly
darker or stronger than darkest picture signals. Sync is considerably
darker or stronger than blanking and dark picture signals. This trouble is caused by excessive signal
input and consequent limiting action in the video amplifier due to incorrect
setting of a.g.c. threshold adjustment. Fig. 8 (Part I) shows the result of same
trouble in video amplifier, as shown in Fig. 12, or incorrect bias and other
troubles in the video amplifier. There is horizontal pulling at top and bottom
of picture and sync is extremely unstable. With complete absence of sync
the horizontal and vertical oscillators may tend to sync on the leading edge of
the blanking signals.

Fig. 12. In this case, sync signals are only slightly darker or stronger than
blanking and dark picture signals. This trouble is caused by excessive signal
input and consequent limiting action in the video amplifier due to incorrect
setting of a.g.c. threshold adjustment. Fig. 8 (Part I) shows the result of same
trouble in video amplifier, as shown in Fig. 12, or incorrect bias and other
troubles in the video amplifier. There is horizontal pulling at top and bottom
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the horizontal and vertical oscillators may tend to sync on the leading edge of
the blanking signals.
information on modifications to correct or improve the condition. Many technicians have learned through actual experience that the best and fastest way to locate sync troubles is by the use of a scope with adequate frequency response which is designed for use with an isolating probe.

**External Interference**

When external interference is present, it frequently causes horizontal pulling or weaving. Usually, in such cases, the interference is clearly evident in the picture and is obviously responsible for the pulling. Occasionally the cause and effect may be confused.

Diathermy interference produced the pulling effects shown in Figs. 15 and 16. These particular examples were photographed because they lack the pronounced herringbone pattern that normally characterizes diathermy interference and for that reason might be mistaken for internal trouble in the receiver.

Any interference that produces beat-frequency bars of sufficient intensity in the picture can result in unstable horizontal sync with accompanying horizontal pulling or weaving, particularly in cases where the beat is a low frequency signal that can readily pass through the narrow-band sync separator.

Obviously, the correct remedy for picture pulling in cases of interference is to eliminate the interference.

In all puzzling cases of horizontal pulling, it is a good practice to observe that cardinal rule of television service—"Check for presence of the same effect on other receivers in the area." This excellent rule requires modification in some cases of horizontal pulling, because it is advisable to check sets of the same model, or at least sets that have the same type of horizontal a.f.c. circuit. Certain rare troubles, such as phase variation in the transmitted horizontal sync signals, may produce noticeable picture pulling in some types of horizontal a.f.c. circuits, but may have only slight effect in other types of a.f.c. circuits.

**Microphonic Pulling**

Picture pulling may show up momentarily whenever the horizontal a.f.c. tube is mechanically shocked or jarred, as by deliberately tapping the tube or through transmitted vibrations from persons walking or dancing near the set. Any relative motion of the elements in the a.f.c. tube results in a variation in the gain, or control action, which produces a variation in horizontal sync phasing. The socket of the a.f.c. tube is usually shock-mounted to minimize such microphonic action. In cases where microphonic horizontal pulling is evident and objectionable, it is advisable to try a new tube in the a.f.c. socket.

**Troubleshooting Procedure**

It may be helpful to summarize some of the facts that we have discussed. We can accomplish two objects by presenting the summary in the form of a troubleshooting procedure.

1. Determine whether the condition is raster pulling or picture pulling. Raster pulling affects the shape of the raster. Picture pulling does not affect the shape of the raster.

2. If it is a case of raster pulling, make checks (depending on the particular symptoms) for trouble in:
   - (a) The "B" supply filter circuit.
   - (b) The horizontal deflection circuits.
   - (c) The deflection yoke.
   - (d) Undesired magnetic field near the picture tube.

3. If it is a case of picture pulling, remember that the horizontal sync signal must pass through the r.f., i.f., and video amplifiers and through the sync separator in order to reach their final destination in the horizontal a.f.c. circuit. Ordinarily, any trouble that causes picture pulling must be in the r.f., i.f., video, sync separator, horizontal a.f.c., or power supply sections of the receiver. With this fact in mind, apply the following checks:
   - (a) Check the amplitude of sync (in relation to the amplitude of blanking and picture signals), as seen on the picture tube, to determine whether the trouble is in the horizontal a.f.c. circuit, or ahead of it, by temporarily removing sync input from the horizontal a.f.c. circuit, free-wheeling the horizontal oscillator, and inspecting the picture to determine whether the pulling is still present. If the pulling is still present, the trouble is probably in the a.f.c. circuit. If the pulling disappears when sync input is removed, the trouble is probably ahead of the a.f.c. circuit; possibly in the sync separator.
Television-tuner alignment can be very profitable for the service man; indeed, as competition increases, the ability to perform this service may become a definite asset to a service business. Fortunately, tuner alignment is not as complicated as it is often believed to be. This article outlines the general principles involved, discusses the equipment required, and outlines straightforward techniques for tuner alignment.

To clear up any misconception that a tuner is a complicated device, consider those essential components and its essentials. Except for the switching arrangement and the usual high- and low-pass filters, it is about as simple as the input circuit of a broadcast receiver. This fact should be remembered when troubleshooting problems arise which are common to all channels. In this case, it is good practice to work with the tuner set to only one channel position until the trouble is corrected. Afterwards, other channel positions can be compared with the initial one for sensitivity, switching noise, and general performance. After the tuner components are checked for alignment, preliminary tests have been completed. Furthermore, the serviceman should be aware that most tuners, unless tampered with, are correctly aligned. This knowledge can often prevent misalignment of a good tuner.

The primary purpose of alignment is to obtain a response curve of proper shape and characteristics of gain and bandwidth. To perform the alignment, the serviceman will require a sweep-frequency generator covering the television channels, an accurate calibrator or marker generator for frequency determination, and a high-gain oscilloscope for observation of tuner response curves. When these instruments are properly connected and adjusted, the curves appearing on the scope give all the information the serviceman needs for proper alignment of the tuner.

Most tuners merely require "touch-up" alignment in which relatively few of the adjustments are used. Generally, alignment "from scratch" is required only when a person without technical know-how, or one having inadequate equipment, has tampered with, or reassembled, the tuner. For the complete realignment job, it is desirable to follow a specific sequence of adjustments, the sequence depending on the type of tuner. Typical sequences are discussed in this article. However, where only touch-up alignment is required, the sequence of adjustment is usually unimportant.

As an aid to alignment, the location and purpose of each adjustable component in the tuner is specified herein by means of sketches which, when used in conjunction with the text, will form the complete illustrations. These illustrations show the primary effect on the response curves caused by varying each adjustment. Thus, the serviceman learns at a glance both what to do and where to do it. The shapes of the curves indicate only the general form of the corresponding traces on the scope. The manufacturer's service data should be consulted to determine the actual characteristics of the corresponding traces on the scope. The manufacturer's service data should be consulted to determine the actual characteristics of the harmonic curve.

Each tuning adjustment has a definite effect on one of seven major factors which, for convenience, are designated as GAIN, FREQ., TRACK, BAND, TRAP, and PEAK. Each of these terms can be associated with one of the symbolic drawings. Arrow points on these symbolic curves point out the most significant adjustment effect.

Use of the Symbolic Curves

The adoption of standards for the negative downward direction of oscilloscope deflection will avoid confusion since the rf lobes are represented as downward because, when rf response curves are observed, the oscilloscope is normally connected through an isolating resistor to the mixer grid and circuit in a tuner, which becomes more negative as signal strength increases. This is so because these response curves usually deflect downward. The tuner if output symbolic curves are shown deflecting upward. The key to these curves may be either upward or downward, depending on the connections to the rectifier. For rf oscilloscope deflection, a horizontal line or arrow pointing to the region which may necessitate further compromises.

Similarly, with respect to horizontal deflection, confusion may be avoided if the high-frequency ends of the response curves are on the right-hand side. This standardization places sound rf carriers to the right of associated picture carriers.

Herefore, rf response curves have usually been shown deflecting upward. This convention arose in part because early scopes were not standardized to provide downward deflection on negative signals. On the basis of upward deflection, points of maximum response are called "peaks," and intermediate dips in response are called "valleys." This same terminology is used in this article for corresponding points on the frequency or actual oscilloscope curves, although the analogy is no longer exact.

GAIN. One of the most important characteristics of a tuner is its gain. In the symbolic curve for this characteristic, the critical region, as indicated by the arrow, is between the sound- and picture-frequency markers. Gain adjustments should be set so that the amplitude at the arrowpoint, halfway between markers, is made as great as possible. For guidance, a vertical hairline may be superimposed on the scope at the frequency at which the amplitude is to be maximized. This maximized amplitude point is often the peak of the single peak type. Nevertheless, the adjustment should always be made to obtain the maximum possible amplitude at the point indicated. This setting may finally have to be a compromise because of the secondary effect of the adjustment on other factors, especially tilt and bandwidth.

TRACK. The symbolic curve for adjustment of oscillator frequency is the conventional discriminator "S" curve with the cross-over point indicated by a vertical line at the "zero-center." This symbolic curve was chosen because in separate-sound receivers, tuner oscillators are usually adjusted to agree with the cross-over point of the discriminator curve. Intercarrier sets, characterized by broad sound tuning, may be tracked with one or several different indications, all beyond the scope of this article. Nevertheless, the familiar S-curve symbol is used to indicate precise tuner-oscillator adjustment.

TRAP. The symbolic curve for the sound intermediate-frequency trap is an M-shaped curve with an arrow pointing to the region which should be adjusted for minimum deflection. In the actual curve the trap frequency is indicated by a marker which may be detected on high-gain oscilloscopes by increasing the input signal and both the vertical and horizontal gains. The expanded marker waveform divides at minimum deflection, when the trap is properly adjusted. An alternate method can be used if audio modulation is available on the marker. In this method, the curve base-line is observed for minimum modulation effect, as indicated by sharp reduction of audio waveform in the base-line as the adjustment reaches the setting for the desired trap frequency.
operate without a trap, but may have an intermediate-frequency peaking adjustment.

**Curve Limits**

On some rf-response curves, particularly the ones which have pronounced valleys, the limit for maximum amplitude deviation between the peaks and valleys is as much as 30 per cent of maximum amplitude. For others, particularly the ones which may be called flat-top curves, the tilt limit may be less. Generally, flat-top curves have both the carrier markers on the flat portion, or if that is not broad enough, the sound carrier may be near the top of the sloping portion of the curve. Manufacturers' specifications should be referred to for these limits.

Commonly, the skirts of the curves may overlap into adjacent channels. Curves that extend beyond adjacent channels usually indicate that alignment has produced broad tuning at the expense of gain.

In typical switched inductor type tuners, broader curves are observed for the high-frequency channels in each band. In variable-capacitor type tuners, the broader curves occur for the low-frequency channels in each band.

Since each type of tuner has its own response characteristics, adjustments should not be attempted without reference to the manufacturer's service data. Where a curve does not meet requirements, it should be studied to determine if the high- or low-frequency portion of the curve is at fault. A comparison should be made to find out whether the fault is common to all channels in the band. If it is not common, or if it appears only to a slight degree on other channels, realignment is of little value, because this condition shows that a compromise between several channel curves is already in effect.

**Alignment Sequence**

As mentioned previously, the arrows on the curves indicate the most important reaction of each adjustment. Often, however, additional effects may be noted on the trace when a single adjustment is changed. When adjustments are made for frequency correction, for example, gain may be lost, and resetting of the gain adjustment may be required. When adjustments are made for tilt, bandwidth may be changed and both frequency and gain may require readjustment. To obtain compromise adjustments, the serviceman after gaining experience, will find it convenient to use two alignment tools simultaneously, each being used on a separate adjustment.

The proper equipment connections for three frequency encountered tuners are given in this article. A sequence of adjustments is suggested for use in the relatively few major realignments.

**Equipment Required**

The requirements for reliable equipment for tuner alignment, as listed below, may seem overly stringent, for most test equipment now in use fails to meet the indicated limits. Actually, the equipment must meet these specifications to be acceptable for alignment of all makes of tuners.

The test signals and scope indications must be reliable. For example, if the sweep generator does not have flat output, the alignment curve will have an unwanted tilt. Under this condition, adjustment for apparent flatness results in an actual response curve which is distorted to compensate for the tilt of the generator signal (See Fig. 3).

**Sweep Generator**

Range: 12 TV channels

Flatness: ± 0.1 db per Mc

Termination: 70 ohms unbalanced

300 ohms balanced

Attenuation: continuous down to 20 uv

Sweep Width: 10 Mc or more (adjustable)

Linearity: ± 15% on scope

Output: Approx. 0.1 volt into 300 ohms

Leakage: Less than 20 uv

**Marker Generator**

Range: 12 TV channels

Output: 0.03 volt or more

Calibration: Crystal, 12 pictures and 12 sound carriers

Attenuation: Approx. 100:1

**Oscilloscope**

Response: 10% max. tilt on 60 cycle square wave.

Sensitivity: 30 millivolts rms per inch or better

Input: Cable, shielded, dc-blocked

Sweep: 60 cps with phasing control

**Preparing for Alignment**

Careful consideration should be given to the fact that tuners are normally well aligned when received from the factory. Therefore, the response curves should be thoroughly examined, by means of the precision equipment recommended above, before any alignment adjustments are attempted.

After the serviceman has decided that realignment is required, he should use the alignment curves as guides and follow the recommended procedure for the specific tuner. Procedures for three frequently encountered tuners are outlined in the following pages.

If the tuner is to be aligned in the receiver, the tuner curves should
be obtained with the first intermediate stage out of operation, in order that if trap and hum reflections may be avoided. Removing the first if tube is generally sufficient to avoid any curve distortion originating in the if amplifier. In some tuners, resonance in the mixer plate circuit may also produce undesirable reflections. Generally, to remedy this situation, the picture intermediate-frequency amplifier input must be loaded, or the if transformer primary must be detuned.

The tuner oscillator should be in operation during alignment. If it is not, the lack of oscillator injection voltage at the mixer grid alters its bias, and the result is an increase in the amplitude of the response curve and a distortion of its shape. Fig. 4 illustrates both this effect and that resulting from failure to remove the first if tube.

If the tuner is to be aligned independently of the receiver, all of the foregoing applies except that concerning the if tube. A substitute receiver chassis, operating at the required intermediate frequency, is needed for oscillator tracking and it can also supply power to the tuner. An unshielded if lead about 15 inches long can connect to the receiver for tracking purposes, but should be removed during curve adjustment.

A necessary preliminary to alignment is a check of the test setup. For example, rf bias should be checked, proper connections for the test leads should be determined, and the output of the generator should be observed. All equipment should be given a 20-minute warmup to stabilize circuits affected by temperature changes.

**Typical Alignment Procedure**

**Standard Coil Company Tuner TV201, RF Alignment:** (a) Connect the sweep and marker generators to the antenna terminals; (b) remove the first picture-if tube; (c) connect a minus 1.5-volt source to the AGC (white) lead of tuner; (d) connect the scope to the test point; (e) align channel 12 in sequence indicated; (f) compare with rf alignment of other channels, and compromise wherever necessary.

**Oscillator Tracking:** (a) Replace the first picture-if tube; (b) connect the scope to the discriminator; (c) apply the channel-12 sweep and the sound-marker generators to the antenna terminals; (d) set fine tuning at mid rotation; (e) adjust the tracking to center the marker on the "S" curve; (f) repeat this procedure for channels 13 through 2.
RF and Oscillator Alignment:
(a) Connect the sweep and marker generators to the antenna terminals; (b) remove the first picture-if tube; (c) connect a minus 1.5-volt source to the AGC (green) lead of tuner; (d) connect the scope through a 10,000-ohm resistor to the junction of Lso and Rs; (e) if major realignment is necessary, set all 12 core-generators to the antenna terminals, and adjust to tentatively center the marker on the "S" curve, with fine tuning at mid-rotation; (f) removing the if tube and connecting the scope to the tuner, repeat the adjustment labeled 1, if necessary; (g) proceed in sequence through step 7. Compromise may be required between the settings for steps 1, 4, 3, and 5.

For each of these adjustments, check the curves for channels 7 through 13; (j) track channels 12 to 7; (k) align channel 6 (steps 9 through 12), then observe channels 2 through 6, compromising wherever necessary; (l) perform step 13.

RCA Tuner KRK-2
RF and Oscillator Alignment:
(a) Connect the sweep and marker generators to the antenna terminals; (b) remove the first picture-if tube; (c) connect a minus 1.5-volt source to the AGC (green) lead of tuner; (d) connect the scope through a 10,000-ohm resistor to the junction of Lso and Rs; (e) if major realignment is necessary, set all 12 core-generators to the antenna terminals, and adjust to tentatively center the marker on the "S" curve, with fine tuning at mid-rotation; (f) removing the if tube and connecting the scope to the tuner, repeat the adjustment labeled 1, if necessary; (i) proceed in sequence through step 7. Compromise may be required between the settings for steps 1, 4, 3, and 5.

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Effects of Sarkes Tarzian RF Adjustments*

<table>
<thead>
<tr>
<th>CHANNEL</th>
<th>MIXER</th>
<th>RF PLATE</th>
<th>ANTENNA</th>
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<tbody>
<tr>
<td>13</td>
<td>LF Tilt</td>
<td>Freq.</td>
<td>HF Tilt</td>
</tr>
<tr>
<td>12</td>
<td>LF Tilt</td>
<td>Freq.</td>
<td>HF Tilt</td>
</tr>
<tr>
<td>11</td>
<td>LF Tilt</td>
<td>Freq.</td>
<td>HF Tilt</td>
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<tr>
<td>10</td>
<td>LF Tilt</td>
<td>Freq.</td>
<td>HF Tilt</td>
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<tr>
<td>9</td>
<td>LF Tilt</td>
<td>Freq.</td>
<td>HF Tilt</td>
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<tr>
<td>8</td>
<td>-</td>
<td>Freq.</td>
<td>HF Tilt</td>
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<tr>
<td>7</td>
<td>-</td>
<td>Freq.</td>
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<tr>
<td>6</td>
<td>Freq.</td>
<td>Freq.</td>
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<tr>
<td>5</td>
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<tr>
<td>4</td>
<td>Freq.</td>
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<tr>
<td>3</td>
<td>HF Tilt</td>
<td>Freq.</td>
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</tr>
<tr>
<td>2</td>
<td>HF Tilt</td>
<td>Freq.</td>
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</tbody>
</table>

1Plus Bandwidth  2Plus Gain  3Plus HF Tilt  4Plus LF Tilt

*Location of three sets of adjustments is indicated on illustration. Tabulated quantities associated with each adjustment can be increased by reducing the coil inductance, either through spreading the coils, shortening the loops, or bending the loops down toward the wafer.
TELEVISION ANTENNAS AND TRANSMISSION LINES

By John R. Meagher
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PART I. ACTION OF DIPOLE AND REFLECTOR

Assume that the metal rod in Fig. 1 is supported horizontally in space to pick up signals from a TV station. The rod is cut to one-half wave length at the frequency of this station. The rod is not broken at the center, and it is not connected to anything.

The rod will intercept or pick up signals from a limited area of space for practical purposes may be considered as being almost as long as the rod and about a half-wave high.

A small amount of this signal will be used up in heat (current flow along the surface of the rod). The rest of the signal cannot be absorbed because there is no load. So essentially all of the signal that is picked up by the rod is re-radiated or sent out again into space.

Suppose we break the rod at the center and connect an adjustable resistance across the gap. Also, suppose that we provide some means to measure the energy in this resistor, which is the load. We then adjust the resistance for the value that develops maximum power in the resistor.

Under this condition, we can assume that one-half of the energy picked up by the antenna is absorbed in the load, and the other half is re-radiated. For convenience, we can assume that the re-radiated energy is consumed in another resistance, which is termed the radiation resistance.

Some of this re-radiated energy can be reflected back into the antenna by placing another rod (reflector) of suitable length in back of the antenna with a spacing of one-quarter wave or less.

The reflector picks up some of the energy that is re-radiated by the antenna. In turn, the reflector re-radiates practically all of this energy, and a portion of this is picked up by the antenna.

The antenna is now getting energy from two sources, from the station and from the reflector. For best results, these two must be in step (or phase) with each other at the antenna. This phase relationship depends on the spacing between antenna and reflector, and on the length (tuning, or phase) of the reflector.

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The reflector acts to increase the energy in the antenna and also to decrease the radiation resistance. In effect, less energy is re-radiated by the antenna and more energy is used in the load.

The same result can be achieved by placing a rod in front of the antenna. In this position it is called a director. The two signals arriving at the antenna, also must be in phase; the phase relation in this case depends on the spacing between the antenna and director and on the received (tuning or phase) of the director.

In TV reception, a practical difference between a reflector and a director is that with a reflector, the response is cut more sharply on the low-frequency side; with a director, "look like" 600 ohms, so that the two in parallel are 300 ohms.

Two quarter-wave lines are used as matching sections between the terminals of each antenna and the transmission line. These quarter-wave lines should have an impedance that will "transform" the impedance of each 170-ohm antenna up to 600 ohms. The quarter-wave line impedance can be computed from the relation:

\[ \text{Line impedance} = \text{input impedance} \times \frac{1}{\text{output impedance}} \]

In this example the Line impedance = \( \sqrt{170 \times 600} = 320 \) ohms approximately.

When tubing or rods are used for the matching sections, the diameter spacing for an impedance of 320 ohms can be determined from Figure 3. Rods of \( \frac{1}{4}\)" diameter spaced 1.8", or rods of \( \frac{3}{8}\)" diameter spaced 2.8" are suitable in this case.

The phasing or polarity of the signal voltage from each antenna is automatically taken care of in this arrangement because the signal from each antenna travels the same distance (\( \frac{1}{2}\) wavelength) to reach the transmission-line terminals.

When stacked arrays for low-band channels are installed, it should be remembered that if the top antenna is not very high above the effective ground plane, the lower antenna will intercept less signal than the top antenna. As a result, the actual voltage gain of the array compared to the top antenna alone, will be less than 1.4.

The effective ground plane may be at roof level in a building with metal framing or a metal roof.

Folded Dipoles

In a conventional folded dipole, as shown in Fig. 4a, with rods of equal diameter, each rod has \( \frac{1}{2}\) the total conducting areas, and the impedance is 4 times that of a plain dipole.

The impedance of a folded dipole may be increased by increasing the area of the continuous section, or by using more than one rod in parallel with the split section, as shown in Figs. 4b and 4c. When the split section has \( \frac{1}{4}\) the total area, the antenna impedance is 9 times that of a plain dipole.

When both reflectors and directors are used to obtain maximum gain, the impedance of a plain dipole may drop to as low as 10 ohms. This value is too low for connection to a coax transmission line. However, a folded dipole with several parallel elements, as shown in Figs. 4b or 4c, may be used in place of the plain dipole to obtain a higher antenna impedance to facilitate matching to a coax transmission line.

In some respects, a folded dipole may be regarded as a plain dipole shunted by two quarter-wave shorted stubs. The stubs function as parallel-tuned circuits, while the dipole functions as a series-tuned circuit. The reactances of the stubs and the dipole change in opposite directions and tend to cancel at frequencies above or below resonance. This tendency contributes to the somewhat wider bandwidth of a folded dipole as compared to that of a plain dipole.
Increasing Signal Input on an Incorrectly Terminated Line

As mentioned later, the impedance of the transmission line should equal the rated input impedance of the particular TV receiver. However, the actual input impedance of TV receivers does not remain constant on all channels, and frequently has a large reactive component. By "tuning out" this reactance on any particular channel, it is possible in many cases to get an appreciable increase in picture strength. Obviously, this expedient is required only on weak signals.

This improvement can be accomplished easily on installations with ribbon-type transmission line. The procedure is as follows:

1. Tune in the weakest TV station.
2. Grasp the transmission line between the thumb and fingers at some point along the line where it is convenient to observe the picture. Slide the fingers along the line, watching for change in picture brightness. At some point, the picture strength will increase. A quarter-wave further along the line, the picture strength will decrease.

The fingers act as a small capacitor across the transmission line. It may be necessary to vary the capacitance by increasing or decreasing the pressure or the finger area.

Find the center point of the section where the hand capacitance increases the picture strength. Connect a small silvered ceramic trimmer (1.5 to either 7 or 15 uF) across the transmission line at this point. Hold the insulator of the trimmer between the tips of the fingers and, using a fibre neut stick, adjust the trimmer for maximum picture strength. Refer to Fig. 5.

Instead of a trimmer capacitor, it is possible to use a piece of metal foil, wrapping it around the line, sliding it to the position for best signal strength, adding or removing foil area if necessary, and finally fastening it in position with Scotch tape.

If hand capacitance decreases the picture strength at all positions along the line, it indicates that the receiver is correctly terminating the line on the particular channel. In this case, no improvement can be achieved.

The actual application of this method of partially compensating for an incorrectly terminated line depends on how many channels need improvement, whether a particular receiver has appreciable input reactance on these channels, and many other factors. We will leave, therefore, the actual application to the ingenuity of the TV technician. It should be noted, however, that the particular position and value of the capacitance apply only to one channel. For any other channel it is necessary to reposition the capacitor and change its value.

PART II—GHOSTS

We did not originally intend to devote much time to ghosts because the subject is generally well understood, at least in regard to the common or garden variety of ghosts. But on analyzing the subject, we were surprised to realize the great variety of ghosts that may, under unfavorable circumstances, unhappily haunt the kinescope. So we decided to make you better acquainted with them.

For instance, have you met all of the following members of the ghost family?

- Leading ghosts
- Trailing ghosts
- Positive ghosts
- Negative ghosts
- Multiple ghosts
- Fluttering ghosts
- Tunable ghosts
- Transmission Line ghosts

If you do not recognize all of them, you may have wasted time trying to eliminate some varieties by orienting the antenna, which doesn't phase them a bit.

**Trailing ghosts**

The usual type of ghost, or echo, or secondary image, is caused by reflection of the transmitted signal from a building or other structure or from a hill or cliff. The reflected signal, which is usually weaker than the direct signal, arrives at the receiving antenna later than the direct signal, and the ghost, therefore, appears on the right-hand or trailing side of the original picture.

**Fluttering ghosts**

Occasionally, in the hope that the plane of polarization of the reflected signal has been changed from horizontal, experimenters try tilting the antenna in various planes to get it at right angles to the plane of the reflected signal. Unfortunately, such trials have usually proved inconclusive or futile.

In Fig. 1B, where the reflected signal is arriving at the receiver from one side, it can be minimized by orienting the antenna for best pickup in this direction.

In Fig. 1C, where the reflected signal is arriving at the receiver from the rear, a reflector on the antenna is helpful because it reduces rear pickup to some extent. As mentioned previously, it is not a cure-all for this condition. A reflector of large dimensions, such as a metal billboard, or a large screen of chicken wire, is generally helpful in reducing rear pickup. In a few cases, it is possible to position the antenna so it is "shaded" from the rear by a closely adjacent steel building.

In mid-city locations, it is sometimes advantageous to orient the antenna for maximum pickup of a strong reflected signal, and minimum pickup of the direct signal. This expedient may be necessary in locations where the direct signal is blocked by an intervening building, as in Fig. 1D.

In locations where several reflected signals from different buildings reach the receiver, there are several ghost images in the picture. These images are referred to as multiple ghosts, or multiple reflections. A typical condition in which multiple ghosts are produced is shown in Fig. 2.

A ghost may be either positive or negative using these terms in their photographic sense, where a negative is a reversed image; that is, the black portions are white and the white portions are black.

Whether a ghost is positive or negative depends on the relative phase of the direct and reflected signals. See Fig. 3. The relative phase depends on the position of the antenna. If the antenna is moved some distance toward or away from the transmitter, the relative phase changes, and the direct and reflected signals either aid or oppose, producing a positive or a negative ghost respectively.

**Fluttering ghosts**

When an aircraft is in the vicinity of the receiver, it reflects signals from the TV transmitter to the receiver. The receiver also gets direct signal from the transmitter. The relative phase of the direct and reflected signals arriving at the receiver changes as the plane travels along. The two signals alternately aid and oppose each other, producing a bright or dull bright and also a flutter in the picture. In TV receivers with automatic gain control on the picture—if amplifier, the fluctuation brightness is largely eliminated. Refer to Fig. 4.

The rate of flutter depends on the position, height, speed, and direction of the plane. The rate of flutter changes as the plane moves along. Occasionally signals from a distant TV station that is beyond normal receiving range may be seen for short periods due to reflection from a plane as shown in Fig. 5. This occurrence demonstrates that the signals are passing overhead and could be intercepted if it were possible to place an antenna high enough in the air.

The usual type of ghost appears on the right-hand side of the picture. It is termed a "trailing" ghost because the reflected signal travels a longer path than the direct signal and arrives later than the direct signal.

There is a condition where one or more images may appear on the left-
This type of ghost appears in locations where the following conditions exist, as shown in Fig. 6:

1. Location relatively close to the transmitter.
2. Considerable signal pick-up in the rf or 1st detector circuits of the receiver, with the antenna disconnected.
3. Long run of transmission line to the antenna.

Because the antenna signal is delayed traveling down the transmission line, the direct signal picked up in the rf or 1st detector circuits appears ahead, or on the left-hand side of the antenna-signal picture. The remedy in this case is—

1. Reduce the direct pickup in the receiver, by shielding the rf and detector circuits, or the entire chassis.
2. Increase the signal from the antenna. (If there is some type of antenna distribution system, it may be defective, or attenuating the signal too much.)

In any case where direct signal pick-up by the receiver is evident in the picture, this signal will be altered by persons moving around the room, or near the TV receiver. (Remember that movement close to an unshielded transmission line will alter the antenna signal, particularly when the receiver does not terminate the line correctly.)

Under the conditions mentioned above but where the transmission line is shorter than a few hundred feet, the direct signal will not appear as a separate image but will blend with the antenna signal to produce a picture of poor quality which will change in quality when someone moves around the room or near the receiver.

In one actual case where leading ghosts were encountered, the following checks were made:

1. With the antenna connected to the receiver, and contrast and brightness correctly adjusted, there were about 12 distinct images in the kinescope.
2. Disconnecting the antenna from the receiver, without disturbing the contrast control, it was found that there were about 10 images.
3. From this it was assumed that the antenna was contributing very little to the signal, and that most of the pickup was from signals "coming in the window" and being picked up in the rf or detector circuits. The numerous images were due to reflected signals from different tall buildings in the vicinity.

4. Shielding of the rf and detector circuits did not help in this case.
5. It was then assumed that the rf tube had no gain, and accounted for the fact that connecting the antenna to the receiver produced very little difference in the picture on the kinescope. This proved to be the trouble: A resistor in the rf bias circuit had dropped to very low value, which resulted in the rf tube being biased off at all times.

6. When this trouble was corrected and the antenna was connected to the receiver, the picture-contrast control had to be turned back considerably because the antenna signal was then being amplified in the rf stage.
7. Letting the contrast control in this new setting, the antenna was disconnected, and it was observed that no images were visible on the kinescope, indicating that at this low-gain setting of the contrast control, the direct signal pickup in the rf and detector circuits was not strong enough, compared to the antenna signal, to cause trouble.
8. The antenna was then reconnected, and after some time spent in observing the correct orientation, the final picture was excellent with only a few very faint reflections or trailing ghosts.

Another case in a similar location was traced to a defective component in the antenna distribution system. These two actual cases are mentioned here because usually the presence of multiple images is blamed on the particular location, and on the position and orientation of the antenna. It is worthwhile, at least, to check for shielding, and to examine other factors, as proved in these two instances.

In working on reflection problems, it is sometimes helpful to know which antenna is acting as the reflecting object in producing a particular ghost.

To locate the reflecting object, it is necessary to say how far the reflection is from the receiver. (Any reflected signal travels a longer distance than the direct signal.)

The additional air-path distance is determined from knowledge of the reflected signal.

1. The scanning spot in the kinescope requires approximately 53 milliseconds of a second, or 53 microseconds, to travel from the left- to the right-hand side of the picture. (Unblanked portion of picture.)
2. Radio signals travel approximately 1000 feet in one microsecond in air. In 53 microseconds a radio signal travels approximately 53,000 feet or 10 miles.
3. Therefore, during the time it takes for the spot to travel from the left- to the right-hand side of the picture, a radio signal travels about 10 miles. The horizontal width of the picture provides a distance scale, somewhat like the range scale on the radar "A" scope.

The procedure in determining the additional air-path distance of the reflected signal is as follows:

1. Adjust the picture width so it is the same size or slightly smaller than the mask, and adjust for the best horizontal linearity.
2. Measure the horizontal distance in inches between a point in the original picture, and the corresponding point in the ghost.
3. Measure the width of the picture in inches.
4. The additional air-path distance in feet is distance between corresponding points x 53,000 inches (Fig. 7)

As an example, if the distance between corresponding points in the original and ghost pictures is one inch, and the width of the picture is 8 inches, the additional air-path distance is $\frac{1}{8} \times 53,000$ or approximately 6,600 feet.

Note that this is the additional air-path distance that the reflected signal travels. It is not the distance from the reflecting object to the receiver, or to the transmitter. For instance, if the distance from the transmitter to receiver is 50 miles, the direct signal travels 50 miles, and in the above example, the reflected signal travels 50 miles plus 6,600 feet.

In this particular example, if the reflecting object were directly in back of the receiver, it would be one-half of 6,600 feet or 3,300 feet in back of the receiver.

To find the buildings or other objects that could produce a ghost with a specific additional air-path distance, it is possible to draw an oval line as shown in Fig. 8. The additional air-path distance of a reflected signal is the same for all points along this line. Any large building or structure along this line can be the reflecting point.

This method is useful only when the distance between transmitter and receiver is relatively short.

Transmission-line ghosts

When the transmission line is not correctly terminated by the receiver, a portion of the signal is reflected at the receiver and travels back up the line to the antenna. If the antenna does not correctly terminate the line, this signal is reflected and travels down the line to the receiver, where it produces a trailing ghost.

With a normal length of transmission line, the reflected signal takes very little time in traveling up and down the line, so it is only slightly delayed and does not appear as a separate ghost. It merges with the original picture signal and affects the picture quality.

With a sufficiently long run of transmission line, the reflected signal appears as a separate trailing ghost.

Occasionally it is necessary to determine whether a particular ghost is due to incorrect termination of the transmission line, or to an external reflected signal. This determination will show whether it is necessary to improve the line termination to correct the antenna.

First determine the additional air-path distance of the ghost, as described previously.

Then determine the equivalent air-path distance, or particular transmission line, which is equal to: length of line in feet x $\frac{1}{k}$

where $k$ is the velocity constant of the particular line and is approximately 300 ohm ribbon line.

As an example, let us assume that the additional air-path distance of a ghost is 4,000 feet and that the 300-ohm transmission line is 500 feet long. Then the equivalent air-path length for 500 feet of 300-ohm ribbon line, for a single reflection is

$$\frac{4,000}{500} = 1200 \text{ feet (approx.)}$$

Because the ghost signal in this example has an additional air-path distance of 4000 feet, it can not be caused by reflection in the transmission line, and it has an equivalent air-path length of 1200 feet.

Tunable ghosts

Echoes that vary in number and intensity with adjustment of the tuning control of the TV receiver are referred to as "tunable ghosts" or tunable echoes, and may be caused by incorrect alignment of the rf picture if amplifiers, or by regeneration.
**PART III**

Why does there appear to be so much contradictory
information about television antennas?

In the first place, there are wide differences of opinion based on individual experience under different conditions.

For instance, technician "A" in a strong signal area is convinced that a certain antenna has broad-band response because it gives satisfactory reception on all of the TV antenna combinations.

But technician "B" in a weak signal area is convinced that the same antenna has narrow-band response, because the maximum strength of several of these antennas, each cut for a particular channel to obtain sufficient signal on each station.

Here are two different opinions. Is this a wide-band antenna, or a narrow-band antenna? How should the manufacturer rate it?

In the second place, almost all of the practical information that is available on antennas applies only to the resonant frequency. This information includes the widely-known values of dipole characteristics such as:

- (a) impedance
- (b) gain from the use of a reflector
- (c) change of impedance due to the reflector.
- (d) and the directivity pattern

All of these characteristics become entirely different when the antenna is used to receive channels at other than the resonant frequency, and this is exactly the frequency that applies in television, because in probably 80% of all TV installations, a single antenna is used to receive two or more stations on different frequencies.

Yet we continue to think and to talk about television antennas in terms of characteristics that apply only at the resonant frequency.

To illustrate this point, assume that a technician stops to admire an antenna installation. He sees that it is a plain dipole cut for one of the low channels, so he classifies it as having 70-ohm impedance. The transmission line is 70-ohm coax, so he is satisfied that it matches the antenna correctly for maximum power output. He knows that a plain dipole has a figure "8" reception pattern, with best reception at right angles to the rods. This dipole is broadside to the direction of the stations, so he is satisfied that it is oriented for best signal pickup.

Of course, the technician is correct on all of these points, but he is overlooking the fact that the antenna has an influence on the actual signal on the particular channel for which the antenna is resonant.

**LOCAL FACTORS**

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**What factors are involved in selecting the best antenna for a particular installation?**

We will name seven factors as shown in Figure 1:

1. The number of TV stations that are to be received, and their frequencies.
2. The field strength of each station at the receiving site.
3. The direction of each station from the receiver.
4. The antenna conditions (echoes or ghosts), and the direction of such reflections, for each station.
5. The interference conditions, rf from electrical for each station.
6. The antenna impedance of transmission line.
7. The price that the owner is willing to pay for material and labor to get good reception on each station.

**How are these factors related to the antenna?**

The number of stations, and their frequencies determine the bandwidth that the antenna must cover.

The signal strength of each station determines whether low-impedance, high-gain, narrow-band, or a combination of such antennas must be used.

Direction, reflection, and interference conditions determine whether a single antenna, or several antennas are required so that each can be oriented for best signal and least reflections.

In addition, the line and receiver impedances may often determine whether plain dipoles or folded dipoles are required.

The cost naturally influences the final choice and may necessitate a compromise. The cost also determines the height which is usually a very important factor in weak signal areas.

**Let's consider a center-city location with three stations, all strong, all in different directions, and severe reflections on all. What is the best antenna?**

The safest answer, without making a survey at the particular location, is to use three separate antennas with reflectors, and three separate transmission lines running to a selector switch near the receiver, as shown in Figure 2.

Each antenna should be positioned on the roof and oriented for least reflections. The antennas should be plain dipoles for 50- or 70-ohm receivers and folded dipoles for 300-ohm receivers.

**Consider a residential area in the city: Five stations, two on the high-band channels, all reasonably strong, all in the same general direction. What is the best antenna?**

For receivers with 300-ohm input impedance, the best antenna in this location is an RCA-225AI or 226AI (the 225AI has a reflector). This is a wide-band dipole. It was designed for these conditions. We will say more about it later.

**Suppose we want to use a 50- or 70-ohm receiver in this suburban location: What antenna is required?**

At least two antennas; one for the low band and one for the high channels. Each to be a plain dipole with reflector. The antenna impedance may be outbalanced by the high losses in the type of transmission line. The antennas may be connected together as specified by the manufacturer, or separate lines can be run from each antenna to a switch near the receiver.

**In very weak signal areas, what is the best antenna?**

A separate "high-gain" narrow-band antenna to the low-band stations and one high-gain antenna for the high-band channels — channels 5 and 6 are generally covered by a single high-gain antenna. Run a separate line for each antenna as shown previously.

It is preferable to use folded dipoles with reflectors and 300-ohm ribbon line for least loss of signal in the line.

However, if noise pickup on the line is excessive, use plain dipoles and reflectors with 50- or 70-ohm coax. But decide this point carefully because coax has much higher loss of signal than 300-ohm ribbon line.

**What is being done to clarify the situation?**

This article is one step in an effort to provide impartial answers to questions about TV antennas.

- We are not including any "how-to-build-it" information. Frankly, the best plan for anyone who wants to build antennas is to copy a design that has been proven for the particular set of conditions.
- The best antenna for television is "best" for all TV installations. The best antenna for a particular location depends on many factors.
In extremely weak signal areas, a stacked array of two antennas may be used for any one station.

When you say a “separate” antenna for a low-band channel, do you mean an antenna that is cut to the correct length so it resonates at the frequency of the particular channel?

Yes. For optimum gain with a half-wave dipole on a particular low-band channel, the antenna should be cut to correct length so that it is resonant at the picture-carrier frequency; it should also be matched to the transmission line.

For satisfactory matching, use a folded dipole for 300-ohm line, and a plain dipole for 50- or 70-ohm line. The line impedance is, of course, determined by the receiver input impedance.

Such an antenna, with a correctly phased reflector, is classified here for simplicity as a high-gain narrow-band dipole.

How can such an antenna cover all the channels in the high band?

It is necessary to think in terms of percentage as shown in Figure 4. Assume an antenna with a bandwidth of 20%:

- at 60 Mc, 20% bandwidth is 12 Mc.
- at 80 Mc, 20% bandwidth is 16 Mc.
- at 200 Mc, 20% bandwidth is 40 Mc.

Obviously for the same percentage bandwidth, an antenna covers more channels on the higher frequencies.

Other factors, such as the ratio of rod diameter to length, increase the bandwidth at the higher frequencies, so it is possible with one plain or folded dipole to cover all the highband channels.

For maximum gain on channels 2, 3, and 4, separate antennas are required, each being designed for its particular channel. Only one antenna is generally required to cover both channels 5 and 6.

The photographs of the WFIL Test Pattern which appear in the preceding articles are reproduced with permission of the station management. The pictures were made by using a receiver in good operational condition except for the specific faults purposely introduced. The quality of test patterns in no way reflects upon the quality of the transmitted signal of WFIL or the station personnel.
This booklet contains a new article by John R. Meagher, well-known author of the RCA PICT-O-GUIDE Series* and many other television servicing publications and articles, covering trouble shooting problems in those hard-to-service television receivers known to many a service technician as "dogs". The information in this article, which supplements the articles by Mr. Meagher in TV SERVICING,* tells the serviceman how to determine the defective component after he has diagnosed the trouble and localized it to a particular stage or section. Emphasis is on time-saving component-checking techniques and on the proper use of test equipment.

*RCA PICT-O-GUIDE Vols. I and II and TV SERVICING (Form TVS-1030) may be obtained from your RCA Tube Distributor, or direct from Commercial Engineering, Tube Department, Radio Corporation of America, Harrison, N. J.
TROUBLE SHOOTING
"TOUGH" SETS OR "DOGS"

By John R. Meagher
Television Specialist, RCA Renewal Sales

Experienced technicians can find the trouble quickly in about 90 per cent of the receivers that require service. But it may take several hours or even days of exasperating effort to find the trouble in the remaining 10 per cent. The latter sets are commonly, and mildly, described as "dogs," because too often they cause a loss which overcomes profits made on other sets.

In service organizations where most of the sets are repaired in the home by experienced field men, it is only natural to expect that a larger percentage of the sets brought into the shop may be dogs.

The time spent on dogs is not wasted if it produces gradual improvement in trouble-shooting methods. A review of past experience with dogs reveals two important facts relating to trouble-shooting methods:

1. When the trouble is eventually found, it is usually in a component that had been checked repeatedly. Often, in the course of working on a dog, a technician will say "I know that the trouble is right in this particular section. I've checked everything in this section. I've tried new tubes, I've replaced several parts. Everything checks OK, but the trouble is still there". Yet, in many cases when the trouble is found, it is in one of the components that had been checked, double checked, and triple checked. Obviously, in such cases there must be something wrong with the method of checking.

2. The trouble almost always turns out to be something "simple", like a capacitor, transformer, coil, resistor, or tube. After all, there is little else in a television receiver. The trouble may be due to slight leakage in a coupling capacitor, shorted turns in a transformer that checks OK for dc resistance, change in value of a resistor that appears perfectly normal, a defect in a tube that presumably had been checked, a stray lump of solder causing a ground or short circuit in a hard-to-see spot, or some intermittently defective part that checks okay when cold.

The trouble in many dogs is not so simple. For instance, it may be a combination of two different troubles in the same section of the receiver. Or, if a set has been worked on for several days, or by several technicians, new and weird troubles may have been added to complicate the original condition: Several leads may have been snipped open for checking purposes, and never resoldered. Worse still, the leads may have been resoldered on the wrong contacts. When a technician fails heir to such a set, he is likely to be inheriting a major headache that only patience, perseverance, and painstaking effort can remedy.

Some technicians create their own dogs by refusing to believe the plain and honest statement that, in many cases of obscure trouble, it pays to check the overall rf alignment. If someone has tampered with the alignment adjustments, or if trouble has developed in an rf or if tuned circuit, the technician may waste many hours checking components and voltages before he realizes that the receiver requires realignment. Unstable sync, incomplete blanking, weak picture or sound, distorted sound, poor picture quality, hum, buzz, snow, and interference, are some of the troubles that are caused by the alignment. If the technician has a convenient set up of good alignment equipment, it takes about 5 minutes to connect the equipment to the receiver and to determine definitely whether the alignment is good or bad. Five minutes spent in checking the alignment may save five hours of fruitless trouble-shooting effort.

In all cases where the trouble is eventually found in a component that had previously been checked as OK, the technician should immediately question his method of checking. Why didn't the fault show up when the component was first checked? Is there something wrong with the method used in checking the particular component?

The purpose of this article is to point out, with complete frankness, the common deficiencies and limitations in the methods and equipment used for checking. This article also contains helpful information and suggestions for checking transformers, coils, resistors, and capacitors: checks which are the foundation of all trouble-shooting work.

Limitations in Methods

1. DC-Resistance checks do NOT prove that a transformer or coil is OK. Even if the measured dc resistance agrees exactly with the values shown in the service data, the transformer or coil may have shorted turns, or other troubles, that seriously affect its operation. Leakage between windings may not show up on an ohmmeter, but may be detected by connecting the coils between a source of high voltage and a high-impedance voltmeter. In most cases, the only reliable method available for checking transformers and coils is the substitution of a new transformer or coil. In many difficult service jobs, the trouble is eventually corrected by installing a new transformer or coil, despite the fact that the original unit checks OK on an ohmmeter.

2. Ohmmeter checks for leakage in a capacitor do NOT always reveal leakage that occurs when normal operating voltage is applied to the capacitor. The voltage applied to a capacitor during ohmmeter check is very low, and necessarily so; otherwise the ohmmeter battery would burn out low resistance elements being tested, such as the filaments of the battery-operated tubes. The voltage across the capacitor in the receiver may be many hundreds of volts. A capacitor that checks OK on an ohmmeter may break down or exhibit leakage under normal operating voltage in the receiver. Leakage, particularly leakage in coupling capacitors, is responsible for the trouble in a high percentage of difficult service jobs.

3. The color code on a resistor does NOT prove that the resistance value is correct. Resistors can increase or decrease greatly in resistance value, or become opened, with no outward change in appearance. An appreciable percentage of obscure troubles are eventually traced to change in the value of a resistor that "looks" OK and has the correct color code.

4. Sparking tests for high voltage do NOT prove that the voltage is sufficient. Sparks can be drawn between the high-voltage lead and the high-voltage electrode of the picture tube, even when the voltage is less than half of normal. Spark tests can mislead the technician into believing that lack of brightness is caused by a perfectly good picture tube. There is no need to guess about the high voltage when it can be measured easily and quickly: An inexpensive RCA WG-289 high-voltage probe enables the owner of any RCA VoltOhmyat* to measure dc voltages up to 50,000 volts. (The WG-289 probe is available for voltomheters that have phone-tip connectors.

**Why a Vacuum-Tube Voltmeter Simplifies Trouble Shooting**

1. **Lead capacitance of 100 - 150 µµf has serious detuning and loading effects in TV circuits.**

2. **Unshielded lead picks up and radiates signals.**

3. **Low input resistance on low ranges causes false indications in many TV circuits.**

Here are some of the things to watch out for:

1. **Ordinary voltmeters (1,000, 5,000, and 20,000 ohms-per-volt) are NOT satisfactory for voltage measurements in high-resistance, high-impedance, and high-frequency circuits of television receivers.** The effects of capacitance loading, resistance loading, stray pickup, regenerative feedback, and radiation from the leads result in false voltage readings that often mislead the technician into believing that trouble exists in circuits where there is no trouble, and vice versa. The voltages indicated by an ordinary voltmeter in many of the circuits in a perfectly normal TV receiver are hopelessly different from the actual operating voltages in the set, and also from those specified in the receiver service data. Those technicians who depend on ordinary voltmeters are needlessly handicapping their own trouble-shooting ability. It is in the technician's best interests to use a good vacuum-tube voltmeter such as the RCA VoltOhmyst. The VoltOhmyst, with its low-capacitance isolation probe, shielded input cable, and extremely high (11,000,000 ohms) input resistance on all dc voltage ranges, has minimum loading and detuning effects on the circuit being tested and, therefore, indicates the true operating voltages.

2. **A CRO that is not designed for use with a low-capacitance probe is NOT satisfactory for checking waveform troubles in the sync separator and deflection circuits.** An unshielded input lead on a CRO picks up stray pulse voltages, and hum voltages, that obscure and alter the desired waveform. It is not satisfactory simply to use a shielded input lead, because the high capacitance of the shielded lead, plus the input capacitance of the CRO (which may total 150-200 µµf), severely reduces the amplitude and waveform of the signal at the test point in the receiver. The resulting pattern on the CRO is incorrect and misleading.

In order to localize a trouble to a particular stage in the video amplifier, sync separator, or deflection circuits, it is essential that the CRO have the following features:

a. **A frequency-compensated isolation probe and shielded input cable.** The input capacitance of the probe should not exceed about 10 or 15 µµf.

b. **Voltage calibration for the vertical amplifier.** Calibration is required in order to determine the voltage amplitude at any point in the waveform of the input signal. The amplitude is just as important as the shape.

c. **Adequate frequency and phase response for observation of horizontal sync pulses.** If the CRO is designed for use with a low-capacitance probe, a frequency response flat to 0.5 Mc, and trailing off to 2 Mc or more, is more than satisfactory, provided the phase re-
response is good. Beware of claims for wide-band frequency response measured at the input terminals of a CRO. Such claims are meaningless and misleading, because the addition of an input lead (a CRO cannot be used without an input lead) drastically cuts down the "rated" frequency response.

In the writer's opinion, the best CRO for television trouble shooting and alignment is the 7-inch RCA WO-56A, which has the three basic requirements of: (1) good low-frequency response, (2) numerous other essential features. For instance, the WO-56A is very much faster and easier to operate for TV trouble shooting and alignment than any other oscilloscope on the market. This truly amazing improvement in the speed and ease of operation is the result of four different features:

(a) Motion of ONE switch instantly changes over the CRO for observation of either horizontal or vertical sync pulses. To make this same change-over with an ordinary CRO, it is necessary to turn different knobs and "fiddle" with two of them. Change-over from observation of horizontal pulses to vertical pulses, and vice versa, is required for efficient servicing of TV trouble troubles in the video amplifier and sync separator are being checked.

(b) The pattern stays locked in position on the WO-56-1 even when the signal level, input frequency, and gain are changed over wide limits. Every technician knows that the user of an ordinary CRO must be continually readjusting the "vernier frequency" and "sync" controls because the pattern jumps out of sync whenever there is a slight change in input level, frequency, or gain. A special sync-limit circuit in the WO-56A minimizes the need for both vernier and critical adjustment of controls.

(c) Dual controls for coarse and vernier adjustments save time and simplify the operation. The WO-56A has the time-saving convenience of dual controls for vertical gain, sync, sweep, and horizontal gain. These controls are positioned in a logical order so that the user doesn't have to waste time hunting around the panel in search for the right knob.

(d) DIRECT-COUPLED push-pull amplifiers eliminate delayed action and bounce in the pattern. The pattern on the WO-56A responds instantly to changes in level, input switching, and centering. An oscilloscope that has resistance-input switching, and centering. In pattern boum·es up and down capacitance coupled amplifiers with low good-frequency response, the pattern bounces up and down whenever it is turned on and returns slowly to rest. Also there is an annoying lag between the adjustment of the centering controls and the resulting motion of the pattern. The direct-coupled amplifiers in the WO-56A have flat response down to zero frequency (de), but there is no bounce and lag. The horizontal and vertical amplifiers are substantially identical, and have frequency-compensated and voltage-calibrated input attenuators.

These four features (instant switching from "V" to "H" sweep frequencies, pattern lock-in, dual and instant pattern response) eliminate the continuous adjustment of controls, and permit the user to devote his full attention to the primary job of television servicing. Every technic peace know that a good CRO is a great aid in TV servicing, particularly in tracking down obscure response down to zero frequency and bounce in the pattern. The pattern stays locked in position on the WO-56A eliminates these objections.

3. Alignment equipment that is built to sell on "price appeal", and that fails to meet any of the minimum requirements listed below, is a good investment at any price.

(a) The rf and if output voltage of the sweep generator must be "flat" over every sweep range, and must remain flat at all settings of the output attenuator. "Peaks and dips" in the sweep output voltage mislead the technician into believing that well-aligned receivers need realignment. When a receiver is aligned with such a sweep, the response curve appears correct, but is actually wrong. There is no satisfactory method, except laboratory analysis, to determine the flatness of sweep curve in such cases. The purchase of this equipment is an act of faith, and is risky. The technician should first check on the number and cost of the crystals that he will have to purchase to accommodate all of the different intermediate frequencies now in use, with more to come. The RCA WR-39C Crystal Cali-
leakage and shorts between coils, leakage and shorts from a coil to the core, leakage and shorts from a coil to the outer container or to the chassis, and similar defects.

Ohmmeter checks also fail to reveal leakage or breakdown (across coils, from coil to coil, from coil to core, etc.) that may occur only when normal operating voltages are applied to the coil or transformer in the receiver. When there is reason to suspect that a short has developed from a coil to the core or to the chassis, a check can be made by temporarily insulating the unit from the chassis.

Checking RF and IF Coils, Transformers, and Traps

If an rf or if tuned circuit can be peaked at its specified frequency, it can be assumed that the coil is OK.

Shorted turns reduce the inductance of a coil and increase the resonant frequency of the circuit. When a circuit cannot be tuned low enough in frequency, inspect the coil for shorted turns. If the coil appears normal, and if there is a fixed or adjustable capacitor in the tuned circuit, check the capacitor for open circuit and for capacitance value. If a satisfactory ohmmeter check is obtained, check the capacitance value. If the value is critical (in, value, and often in construction), it is advisable, and frequently essential, to use exact replacements.

When the inductance or capacitance of a tuned circuit is too low, it is possible to be misled by a false peak in response which occurs when the iron core in the coil is moved through the maximum inductance position at the center of the coil. If the core can be moved from one end of the coil to the other, there are two possibilities (one on each side of the center of the coil) at which the circuit can be resonated to the correct frequency. In some tuned-circuit transformers, and in some tuned coils that have a coupled wave trap, it is necessary to use a particular one of these two settings in order to get a clear difference in coupling between windings. The correct setting is usually specified in the service data.

When it is impossible to peak a tuned circuit or trap at the specified frequency, check the dc resistance of the coil for open, for shorted, inspect the leads from the coil, and the terminal connections. If necessary, temporarily disconnect and check the associated tuning, coupling, and bypass capacitors, and any shunt damping resistor. If these parts check OK, try a new coil.

Coils that are wound with spaced turns of bare wire can be checked visually: Look for short between adjacent turns, and for splashes of solder across the turns. If there is a tap on the coil, or a capacitor mounted on the coil, make certain that the connecting bus leads are not shorting against the coil.

Video Peaking Coils

Video peaking coils are used to "hold in" the high-frequency response, from about 2 to 4 Mc, in the second detector and video amplifier. A shorted peaking coil reduces the definition of the picture slightly. An open peaking coil results in complete loss of picture, or serious loss of picture quality. The effects of open and short circuits may be summarized as follows:

(a) A complete short circuit, or shorted turns, in one peaking coil usually causes only a minor loss in the definition ("sharpness"), or fine detail of the picture.

(b) If the peaking coil has a damping resistor connected across it, an open circuit in the coil leaves the damping resistor in the circuit; consequently, there is seldom complete loss of picture, but there is usually a noticeable loss of picture quality and, in some cases, poor sync action.

(c) If the peaking coil does not have a damping resistor connected across it, an open circuit in the coil is likely to result in complete loss of picture. For instance, if the coil is in series with a video plate circuit, an open coil creates an open plate circuit, with resulting loss of picture.

When the visible symptoms indicate that the trouble is in the video amplifier, it is advisable to check the dc resistance of the peaking coils, especially for turns from about 2 to 10 ohms, depending on the size of the wire and the inductance of the coil. If a coil is found to be opened or shorted, it should be replaced.

As mentioned above, a shorted peaking coil has little effect. This fact can be used to advantage when it is found that loss of picture, or poor picture quality, is caused by an open peaking coil. To make a temporary or emergency repair on an open peaking coil, simply connect a short circuit across it.

If the damping resistor across a peaking coil becomes opened, there is seldom any visible effect in the picture. Loss of damping, ever, cause "ringing" in the particular circuit. Ringing may produce multiple images on all stations. The images are uniformly spaced and progressively weaker. When multiple images are caused by external signal reflections from several surrounding objects, the images are not uniformly spaced, not progressively weaker, and are seldom identical on all stations. Video ringing can also occur in a circuit consisting of a peaking coil connected in series with a load resistor, if the resistor is shorted out.

In order to check the dc resistance of a shunt damping resistor, it is necessary to disconnect one end of the peaking coil from the resistor. In some receivers each of the peaking coils is muted off and connected to, a small tubular resistor. The resistor may or may not be used to provide damping across the coil. If the resistor is not in use, and it is desirable to provide damping, it usually has a value under about 25,000 ohms. If the resistor is used solely as a convenient means for mounting the coil, it has a relatively low resistance value.

Width and Linearity Coils

If the raster is visible on the picture tube, adjust the iron core in each width coil and in the linearity coil, from the maximum-inductance position (core at center of coil), to the minimum-inductance position (core out of coil). If the amplified response, from about 2 to 4 Mc, in the horizontal output transformer circuit appears normal for the particular receiver, it may be assumed that the coil is OK. If adjustment of the core has little or no effect, or if this check cannot be made due to absence of the raster, disconnect one end of the coil and check the dc resistance. If the coil is definitely opened or shorted, it should be repaired or replaced. If the coil appears to be OK, check the associated circuits and components.

Power Transformers

When a power transformer operates considerably hotter than usual, the trouble may be caused by external over-load in one of the secondary circuits or by internal over-load due to shortened turns in the primary or in one of the secondary windings. As mentioned previously, shortened turns in a winding are equivalent to a secondary winding (of the same number of turns), which is shunted out. The current that can flow in the shorted turns is limited by the size of the wire and other factors. There is usually higher current and higher power loss in a shorted turn on a "heater" winding than on a B-supply winding.

A transformer can be checked for excessive power loss, due to shorted turns or internal fault, by disconnecting all of the associated secondary windings, and operating the transformer until it attains maximum temperature. If the transformer becomes excessively warm or hot, it is a definite sign of internal trouble.

An external short circuit or overload can be localized to a particular secondary circuit by the following method:

1. Remove the power plug and disconnect all of the secondary windings.

2. Remove all of the tubes from the receiver. Remove the socket from the picture tube.
3. Connect one of the heater circuits.

4. Apply power to the transformer. Look for signs of overloading. If a heater circuit does not cause over-load, insert the tubes that are operated from this heater winding. Look for signs of over-load as each of these tubes is inserted. If there is no evidence of over-load, it may be assumed that this particular heater circuit is OK.

5. Turn off the power, connect the next heater winding, and proceed as in item 4.

6. Check all of the heater circuits, and, finally, the B-supply secondary.

### Checking Tubular Resistors

On most service jobs, the tubular resistors can be checked simply by visual inspection. If a resistor is not discolored, charred, swollen, cracked, or broken, and if the color code agrees with the resistance specified in the schematic diagram on the receiver, it may be assumed that the resistor is probably OK. But, if a thorough check of the tubes, components, voltages and wiring in the suspected section of the receiver fails to reveal the fault, it is then definitely advisable to measure the actual resistance of each resistor in the given section of the set. Resistors can increase or decrease in resistance value, and also become opened, without the slightest alteration in external appearance. In addition, there is always a remote possibility that the color coding on a resistor may be incorrect, and that certain colors such as yellow or bluish-green and greenish-blue, may be mistaken. For these reasons, it is a good rule, particularly when working on difficult jobs, not to accept the resistors at "face value", but instead, to measure the resistance of each resistor.

A resistor rarely becomes overloaded through any fault of its own. Overload is almost always caused by an external short circuit or ground in one of the associated components. Hence, when a resistor shows visible signs of overload, it is not sufficient merely to replace the resistor. It is essential to check for possibility of short circuit and grounding in the associated circuit components and wiring. Resistor overload is frequently caused by excessive leakage or short circuit in the associated bypass capacitor, but it may also be caused by a defective tube, incorrect voltages on a tube, leakage in a coupling capacitor, grounding in an associated coil or transformer, or similar defects.

If the reason for the overload cannot be determined, it is advisable to install a new resistor, and to operate the receiver for sufficient time to see if the condition recurs. If the resistor becomes excessively hot, quickly check the voltages in the resistor circuit to determine the point at which the short circuit or grounding is taking place. It may be necessary to snip open any associated bypass capacitance or other component, to determine whether it is responsible for the overload.

Many technicians have asked how much change can be tolerated in resistance values. It is impossible to give a general answer to this question because some circuits are more critical than others. For example, a change of 10 per cent in the value of a grid-bias resistor for a video stage may cause trouble, while a change of 50 per cent in the grid-leak resistor of the same stage may have little if any effect. Circuit constants are selected by the design engineers to provide the best possible performance over the range of operating conditions, including high and low line voltage, high- and low-limit tube voltages, high- and low-limit temperatures in other components, high and low room temperature, etc. If a resistance value appears to be unimportant for a particular set of operating conditions, it may possibly be important for a different set of conditions. It is therefore sensible to adhere to the specified values as closely as possible. When a defective resistor is replaced, it is good practice to replace it with a unit of equal or better tolerance, or measure the replacement with an ohmmeter.

The task of checking all of the resistors, and the dc resistance of all other components in the suspected section of a receiver, can be simplified and speeded up by the use of the RCA VoltOhmyst. Ordinary voltohmmeters, and many vacuum-tube voltohmmeters impose the continual nuisance and more critical than others. For example, a change of 10 per cent in the value of a grid-bias resistor for a video stage may cause trouble, while a change of 50 per cent in the grid-leak resistor of the same stage may have little if any effect. Circuit constants are selected by the design engineers to provide the best possible performance over the range of operating conditions, including high and low line voltage, high- and low-limit tube voltages, high- and low-limit temperatures in other components, high and low room temperature, etc. If a resistance value appears to be unimportant for a particular set of operating conditions, it may possibly be important for a different set of conditions. It is therefore sensible to adhere to the specified values as closely as possible. When a defective resistor is replaced, it is good practice to replace it with a unit of equal or better tolerance, or measure the replacement with an ohmmeter.

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(or dropping) resistor. As a result, the resistor may become burned open, or it may change considerably in resistance value. Whenever a plate or screen-bypass capacitor becomes shorted, it is always advisable to check the associated filter resistor and any other components that may have been overloaded as a result of the shorted capacitor.

When a suspected bypass capacitor is disconnected (in checking for possibility of short circuit), the absence of the bypass capacitance may affect the normal operation and voltages of the suspected device. In such cases, the voltages will not return to normal until a new bypass capacitor is connected in the circuit.

2. Shorted or leaky coupling capacitors are usually detected by dc voltage measurements. If the grid-bias voltage in a particular stage is considerably less than normal, or if it is positive, the coupling capacitor should be checked for possibility of leakage, as described later, or a new capacitor should be temporarily substituted for the suspected capacitor to see if it remedies the trouble.

In oscillator circuits (rf, horizontal, and vertical): the normal negative grid-bias voltage is produced by grid current that flows during positive peaks of the oscillator signal. If the grid-bias voltage is very low, or considerably less than normal, it is necessary to check all of the components in the oscillator circuit, including the grid capacitor.

In circuits such as the horizontal discharge, horizontal output, or some sync-separator stages, where the normal grid-bias voltage is obtained entirely or in part as a result of grid current on positive peaks of the applied signal, low-bias voltage is often due to insufficient input-signal voltage.

Methods of checking for leakage in coupling capacitors are described later.

3. Opened capacitors are detected by temporarily connecting a good capacitor across each of the suspected capacitors, one at a time, as shown in Fig. 2. If connection of the good capacitor restores the normal operation of the circuit, it may be assumed that the original capacitor is opened.

Good capacitors in certain circuits may be connected or disconnected with no apparent effect on the performance of the receiver. There are several possible explanations in such cases: (1) There may actually be a slight effect which the observer fails to notice. (2) The effect may be apparent only under the particular operating conditions. (3) The particular capacitor may not be essential, but may have been incorporated as a precautionary measure. For instance, in many receivers, extra capacitors and resistors are used in the intermediate-frequency plate, screen, and grid decoupling networks as an additional safeguard against possibility of regeneration.

4. Any faulty capacitor in any circuit can be detected by the "substitution" method, as shown in Fig. 3. Disconnect the "high" end of the suspected capacitor. Temporarily connect a good capacitor in the circuit. If the trouble is still present, after the new capacitor is connected, it may be assumed that the original capacitor is defective. Obviously, in the latter case, a new capacitor should be installed permanently. The new capacitor should have the correct capacitance and the correct voltage rating, or a higher rating. The new capacitor should be of the same type (papered, mica, ceramic, etc.) as the original, and it should have the same temperature coefficient, if the original capacitor has temperature compensation.

When the substitution method is used for checking bypass and coupling capacitors, the capacitance of the testing capacitor is not critical in most circuits. Ordinarily, the testing capacitor may have a value anywhere in the range of from 1/4 to 2 times that of the original capacitor. Even a value of from 1/4 to 10 times that of the original capacitor is likely to be satisfactory for the purpose of revealing defects in the original capacitor.

However, when deflection circuits are checked for the cause of poor linearity, and when deflection oscillator and discharge circuits are checked, the rated capacitance of the testing capacitor should be the same as that specified for the original capacitor.

In rf and if tuned circuits, the testing capacitor should be an exact duplicate of the original capacitor. In rf tuned circuits, even the lead lengths on the testing capacitor should be the same as on the original.

Many technicians keep a selected assortment of capacitors solely for use in substitution checks. The larger capacitors, such as electrolytics, may be equipped with leads and clips for convenience in connection.

Even in circuits where the capacitance value appears to be unimportant, the replacement capacitor (the capacitor that is permanently installed in place of the defective one) should be an electrical duplicate of the original. In rf and if tuned circuits, the replacement capacitor should duplicate the original both electrically and physically.

In high-frequency rf and if circuits, it is NOT good practice to parallel two or more capacitors in order to obtain the desired capacitance value: a dip or a peak may be produced in the response band of the amplifier at the resonant frequency of the paralleled capacitors, if this frequency happens to fall within the band.

Some tubular capacitors have a dark line printed around one end of the label with the words "ground," or "outer foil" to indicate that the pig-tail on this end is connected to the metal-foil plate that is on the outside of the rolled-up assembly. It is a good general practice to connect the outer-foil end of the capacitor to the grounded or low-impedance side of the circuit. When the outer-foil plate of the capacitor is grounded, it forms an electrostatic shield around the capacitor, thus reducing the amount of stray coupling to and from other nearby components and wiring.

Checks for Leakage

No resistance limits have been established in television service practice for classifying a capacitor as "leaky" or "not leaky" because the effects of leakage depend on the particular circuit in which the capacitor is used as shown in the following examples:

a. A partial short circuit (low-resistance leakage) of 1,000 ohms in a capacitor connected across a 100-ohm cathode resistor has very little effect on the operation of the circuit. Such leakage is likely to pass unnoticed unless the technician happens to disconnect the capacitor and check it for leakage. A leakage of 1,000 ohms in a plate or screen-circuit bypass capacitor, or in a plate-to-grid coupling capacitor seriously affects the voltages and the operation of the circuit.

b. A leakage of one megohm in a plate or cathode bypass capacitor ordinarily has negligible effect on the operation of the circuit, but the same leakage in a plate-to-grid coupling capacitor is practically equivalent to a short circuit in most cases, and will definitely affect the operation of the circuit.

c. A leakage of even 100 megohms (100,000,000 ohms) in a plate-to-grid coupling capacitor is likely to cause trouble if there is a high-value resistance in the grid circuit. Consider the following conditions:

- Plate voltage = 300 volts
- Normal grid bias = -8 volts
- Grid resistance = 2.0 megohms
- Leakage in coupling capacitor = 100 megohms

In this example the voltage drop across the grid resistor due to leakage in the coupling capacitor is almost 6 volts (2/102 x 300). This voltage bucks the normal grid bias,
reducing it from -8 to -2 volts. Such a large percentage of change in grid-bias voltage is very likely to cause trouble.

(d) Even a leakage of 1,000 megohms (1,000,000,000 ohms) may cause trouble, as in the following case:

<table>
<thead>
<tr>
<th>Plate voltage</th>
<th>= 300 volts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal grid bias</td>
<td>= -2 volts</td>
</tr>
<tr>
<td>Grid resistor</td>
<td>= 2.5 megohms</td>
</tr>
<tr>
<td>Leakage in coupling capacitor</td>
<td>= 1,000 megohms</td>
</tr>
</tbody>
</table>

The drop across the grid resistor due to leakage in this case is approximately 0.6 volts (12/1002 x 300), which reduces the grid bias from -2 to -1.4 volts. If this condition existed in a video amplifier, it might result in sync clipping and unstable sync action.

In many cases of obscure trouble, the fault is eventually corrected by replacing a coupling capacitor that "checks OK" on an ohmmeter. When a faulty capacitor, or any other faulty component, appears to check OK, the technician is likely to spend many hours of exasperating effort checking other components before he finally decides to try a new capacitor. Obviously it is senseless to depend on checks that fail to reveal the fault:

For practical purposes, the best way to check for leakage in coupling capacitors is by measuring the "leakage voltage" across the grid resistor while the receiver is in operation and while normal operating voltage is being applied to the capacitor. For a thorough understanding of this method, it is necessary to understand the different ways in which grid-bias voltage is obtained, and how it can be measured. This entire subject is necessary to understand the different ways in which grid-bias voltage is obtained, and how it can be measured. This entire subject is covered, as briefly as possible, in the following illustrations and text.

The actual grid-bias voltage is the dc voltage between the grid and cathode, as indicated in Fig. 4. Voltages shown in service data are usually measured with respect to the chassis, but in many circuits the voltage from grid to chassis is not the actual grid-bias voltage.

In Fig. 5, the voltage from grid to chassis is zero, but the actual grid-bias voltage, obtained by the voltage drop across the cathode resistor, is 10 volts.

In Fig. 6, the actual grid-bias voltage is -10 volts, measured either with respect to the grid, or with respect to the cathode, because the cathode is connected directly to the chassis.

In Fig. 7 the actual grid-bias voltage is -10 volts, obtained by the drop across the top resistor in the cathode circuit. The grid-to-chassis voltage is the same as the voltage across the bottom resistor in the cathode circuit.

In Fig. 8 the actual grid-bias voltage is -10 volts, obtained by the drop across the cathode resistor. Grid-to-chassis voltage is -100 volts. Voltage measurements from grid to chassis, or from cathode to chassis, are likely to be misleading in circuits like Figs. 7 and 8. Refer also to Fig. 9.

Grid-to-chassis voltage is -100 volts. Voltage measurements from grid to chassis, or from cathode to chassis, are likely to be misleading in circuits like Figs. 7 and 8. Refer also to Fig. 9.

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In Fig. 9 the same as Fig. 8 except that a partially-shorted cathode bypass capacitor has reduced the voltage across the cathode resistor, and also the grid-bias voltage by 50%, from 10 volts to 5 volts. If the technician measures the grid-to-chassis voltage, which is still -100 volts, and the cathode-to-chassis voltage, which is 95 volts instead of 90 volts, he is very likely to assume that there is no trouble in the circuit, since he is aware that the negative supply voltage (-100 volts in this example) is frequently 10% high or low. In circuits of this type, it is best to measure the voltage across the cathode resistor, and also the voltage from grid to cathode. Refer to Fig. 10.

The service data for the receiver may not show the voltage across the cathode resistor, but it may give the voltage at each end of the resistor, measured with respect to the chassis as shown in Fig. 10. The voltage across the cathode resistor is the difference between these two voltages. (12 volts in this example).

The required grid-bias voltage for a tube is sometimes obtained by using two grid resistors to divide the voltage from an available negative-supply tap, as shown at left in Fig. 11. The required grid-bias voltage is shown in an equivalent form at the right in Fig. 11. In this particular example, the resistors are equal in value, and they divide the total voltage in half, but any other fraction of the voltage may be obtained by changing the ratio of the two resistors. The effective grid-reistance is equal to the value of the two resistors in parallel, or 6.5 megohms in this example.

NOTE: In conventional rf and if amplifiers, there is no grid current and (if there is no leakage in the coupling capacitor) there is no dc voltage across the grid resistor. (An exception may occur in a stage in which the cathode-resistor bias is less than 1.5 volts and the grid resistor has a value of more than about one megohm. Then, current due to "contact potential" may produce a slight negative voltage across the resistor.) This condition of zero dc voltage across the grid resistor is shown in examples given in Figures 12 to 15 inclusive. If the grid-coupling capacitor is shorted or leaky, the leakage current produces a dc voltage across the grid resistor, as shown in Figures 18 and 23.

Grid-bias voltage in oscillators is obtained (entirely or in part) as a result of electron flow from cathode to grid during the positive half-cycles of oscillator voltage on the grid. The electrons charge the grid capacitor, making it negative on the grid side. In the time between positive peaks, the capacitor discharges through the grid resistor, thus producing a voltage across the resistor as indicated in Fig. 12. This voltage is termed the "developed" grid-bias voltage, and it is a measure of the oscillator activity. If the developed bias voltage is lower than normal, it indicates trouble or misadjustment. If oscillation ceases, the developed bias voltage drops to zero, and the plate or screen current may become excessive. A resistor may be used in the cathode circuit to provide protective bias voltage and to prevent tube damage in the event that the circuit stops oscillating.

In certain amplifiers and limiters, the grid-bias voltage is produced as a result of grid and electron flow during the positive half-cycles of the applied input signal. The developed grid voltage [Fig. 13] is a measure of the amplitude of the applied signal. If the developed grid voltage is appreciably less than normal, it indicates either that the amplitude of...
the applied signal is below normal, or that there is trouble in the circuit, including the possibility of leakage in the coupling capacitor.

A resistor may be used in the cathode circuit to provide bias voltage and to prevent tube damage in the event that the input signal fails, or becomes too weak.

In Fig. 14, which shows the circuit of a typical horizontal-output amplifier, the grid-bias voltage is 

\[ V_{grid} = 10 \text{ volts} \]  

obtained by the drop across the cathode resistor, and 

\[ V_{cathode} = 15 \text{ volts} \]  

produced as a result of cathode-to-grid electron flow during the peaks of the positive half-cycles of the input signal. The developed voltage across the grid resistor is a measure of the amplitude of the applied signal. If the developed voltage is appreciably less than normal, it indicates that the amplitude of the applied signal is below normal, or that there is trouble in the circuit, including the possibility of leakage in the coupling capacitor.

In circuits where the cathode is returned to a relatively high negative voltage point in the B-supply circuit, as shown in Fig. 15, it is important to realize that voltage measurements made from grid to chassis are very likely to be misleading. The voltages in the power supply are often 10% higher or lower than the values specified in the service data. Therefore, if the grid-to-chassis and the cathode-to-chassis voltages check within ±10% of the specified values, the technician is likely to assume that everything is OK. Actually, such checks do NOT reveal troublesome changes in developed voltage across the grid resistor, nor in the voltage across the cathode resistor. Assume that the voltages shown in Fig. 14 are correct, and that in Fig. 15, certain trouble has changed the developed voltage from 

\[ 15 \text{ volts} \]  

to 

\[ 5 \text{ volts} \]  

and has changed the voltage across the cathode resistor from 

\[ 10 \text{ volts} \]  

to 

\[ 5 \text{ volts} \]  

because only the rated voltage is given, considerable percentage of error may result when the voltage across the resistors is computed. Owing to the difficulty of reading within a few volts on the higher-voltage scales of a voltmeter, the service data should show the developed voltage across the grid resistor, and the voltage across the cathode resistor.

In Fig. 17 the grid-bias voltage on the second tube is 

\[ -10 \text{ volts} \]  

This may be determined from these other voltages, In the example shown, the voltage across the grid resistor is 

\[ 16 \text{ volts} \]  

and the voltage across the cathode resistor is 

\[ 9 \text{ volts} \]  

The service data should give the exact measured value of the negative-supply voltage, but in many cases
age across the grid resistor that "bucks" the normal bias voltage, as shown in Fig. 18.

In Fig. 18, leakage of 100 meg-ohms (100,000,000 ohms) causes a voltage drop of -6 volts across the grid resistor. This voltage bucks the normal grid-bias voltage, reducing it from the correct value of -10 volts to a troublesome low value of -4 volts.

Ohmmeter checks often mislead the technician into believing that a leaky coupling capacitor is OK. The low testing voltage in ohmmeters is often inadequate to reveal high-resistance leakage, and it fails to reveal leakage that may exist when normal operating voltage is applied to the capacitor. Both of these failings can be overcome by checking the "leakage voltage", as shown in Fig. 19, 20, 21, 22. The check is made with the receiver turned on and with normal circuit voltage applied to the capacitor. The instant the probe is touched to the capacitor, the meter pointer will be deflected, but if the capacitor is OK, the pointer should return to zero.

If the grid circuit is returned to a negative voltage point (such as -50, -100, -150 volts) the operating voltage applied to the capacitor is equal to the plate voltage plus the "C" voltage. The full voltage is used in checking the capacitor for leakage by connecting the VoltOhmyst as shown in Fig. 20.

The voltage produced across the grid resistor, as a result of any leakage in the coupling capacitor, can be measured as in Fig. 21 and 22.

In circuits where the grid-return is not connected directly to chassis, connect the VoltOhmyst across the resistor, as shown in Fig. 22, to measure the leakage voltage across the grid resistor.

An ordinary voltmeter (1000, 5000, or 20,000 ohms per volt) gives completely wrong and misleading indications of leakage voltage, as proved in the examples shown in Fig. 23. In the first example, the reading on a 20,000 ohm-per-volt meter misleads the technician into believing that the leakage is only 0.3 volt, whereas the actual leakage voltage is 6.0 volts, a value which will cause definite trouble in most cases. In the second example, the leakage voltage of 0.6 volt is likely to cause trouble in a video amplifier that has a low bias voltage (in the order of 2 volts). A 20,000 ohm-per-volt meter indicates only 0.03 volts for this same leakage, thereby leading the technician into the erroneous belief that the capacitor is OK. (Moral: Don’t handicap your trouble-shooting ability, and don’t run the risk of turning simple service jobs into difficult dogs, by depending on the misleading indication of ordinary voltmeters. Use a meter that will help you, not mislead you. Use a good vacuum-tube voltmeter.

It is sometimes advisable to check for possibility of leakage in a new capacitor before installing it in the receiver. Paper, mica, and ceramic capacitors can be checked for leakage as shown in Fig. 24. Select B+ and B- points in the receiver that provide a voltage approximately equal to the rated voltage of the capacitor. Use a low de-voltage range on the VoltOhmyst.

A shorted or leaky coupling capacitor in an age-controlled if amplifier affects the voltage on the agc bus and at the grid of each of the controlled tubes. Disconnect one coupling capacitor at a time and check it for leakage voltage as in Fig. 25.

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