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GE Electronic TUBES
Techni-talk on AM, FM, TV Servicing

COLOR TV-V

In this issue the NTSC signal will be described. The frequencies used, the bandwidth, and the development of the chrominance signal will be discussed.

The NTSC system uses the same 6 MC channel for color as is used for monochrome transmissions. A monochrome transmission requires two carriers, one video and one sound. A color transmission requires the same two carriers used in a monochrome transmission plus a color subcarrier as shown in Fig. 1. This color subcarrier is amplitude modulated by two chrominance signals which are ninety degrees out of phase with each other. The two chrominance signals are indicated as R-Y and B-Y in Fig. 1.

COLOR SIGNAL BANDWIDTHS

It will be noted that the two color signals shown in Fig. 1 have different bandwidths. These bandwidths were specified by NTSC only after a considerable amount of research and investigation regarding the reproduction of a satisfactory televised color picture. It was found that the eye cannot distinguish fine color detail. Some colors such as blue cannot be distinguished from green. Other colors such as red and yellow look like orange when viewed from a distance. An example of this can be found in woven material such as that used in men's suits. It will be found that a great many of these fabrics contain colored threads of a different color than the fabric. The color of these threads can only be seen by close inspection and blend into the over-all color when viewed from a few feet. If a suit made of this type of material appeared on a color television screen it would only be necessary to have the over-all color reproduced and not the fine detail.

Some colors such as blue and green would ordinarily be seen only in large color areas such as clothes, drapes, backdrops, etc. Since large areas of color will produce low frequency signals a bandwidth up to 0.5 mc was decided upon for the B-Y signal.

The type of scene which predominates in most television programs is a close-up view of people. The color detail as well as faithful color reproduction will be important in close-up scenes because hair and eye colors as well as flesh tones are easily recognized. Since most flesh tones are within this range of the R-Y signal it was decided that this signal should have a bandwidth of 1.5 mc which is three times as wide as assigned to the B-Y signal.

Since both the R-Y and the B-Y color signals have been inserted in the same modulation envelope used for the brightness or Y signal, a very pronounced interference pattern can be expected. This type of interference has been reduced to a minimum by carefully selecting the subcarrier frequency and by eliminating the color carrier at the transmitter. Each of these will be discussed.

SUBCARRIER FREQUENCY

When the color subcarrier frequency was decided upon it was necessary to make it as high as possible. This reduced the visibility of any interference pattern resulting from the beat or difference frequency between the picture carrier and the color subcarrier. Since the sound carrier had already been established at 4.5 mc, the maximum bandwidth available for video information was 4.2 mc as shown in Fig. 1. It was also established that the upper sidebands of the color subcarrier should extend at least 0.6 mc above the subcarrier. Therefore the

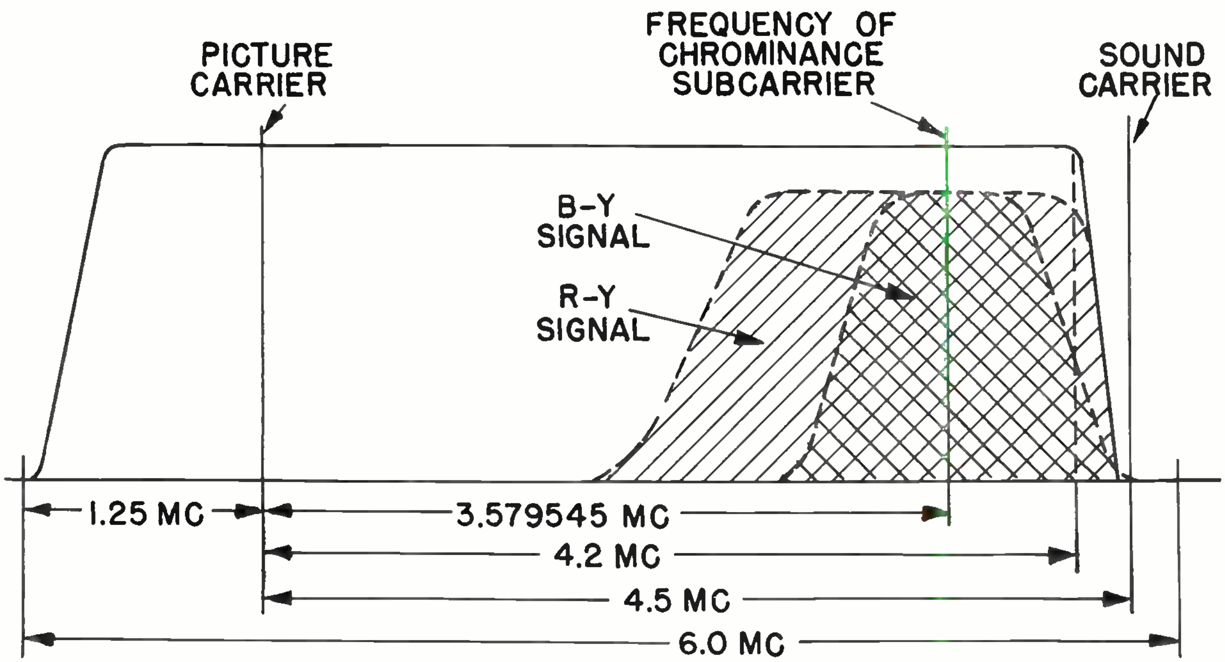

Fig. 1. Six megacycle television channel showing the position and bandwidth of the chrominance signals.

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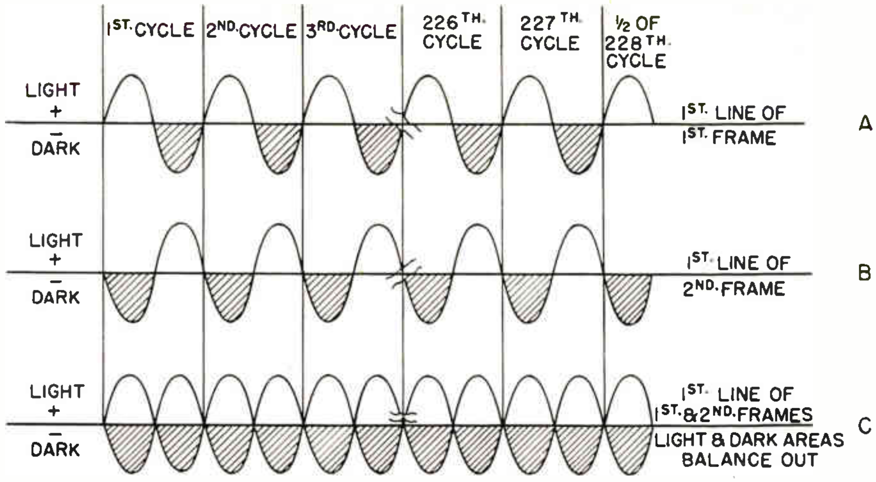

Fig. 3. Illustration showing cancellation effect of subcarrier frequency interference pattern.

maximum frequency that could be used for the subcarrier was 3.6 mc.

Another factor which determined the actual frequency was a discovery back in 1934 by Pierre Mertz and Frank Gray. Their studies indicated that during the scanning process used in telephotography the energy produced was bunched at specific multiples of the scanning rate. This means that in monochrome transmission the brightness or video information would be concentrated at harmonics of the field and line frequencies. Since most of the energy occurs at a line frequency rate rather than at a field rate, the line frequency has a much greater effect on the video signal than the frame frequency, and causes most of the energy contained in the video signal to be bunched at harmonics of 15,750 cycles rather than 30 cycles. This statement is true only if there is little or no motion in the scene scanned. Since the largest area in most scenes is not in motion, the greatest amount of energy would still occur at harmonics of 15,750 cycles as shown in Fig. 2A.

It is beyond the scope of this article to go into a detailed discussion of the energy distribution within the TV signal; therefore for the purpose of this article we ask you to accept the fact that by selecting a frequency which is an odd multiple of half the line frequency for the color subcarrier, the energy in the color signal will fall in between harmonics of the line frequency as shown in Fig. 2B. This is known as frequency interleaving.

It was previously stated that the subcarrier frequency should be as close as possible to 3.6 mc which was the highest frequency which could be used for the subcarrier. Since this frequency would have to be an odd multiple of half the line frequency, the closest odd multiple of 7875 cycles to 3.6 mc would be 457. The subcarrier frequency would then be 3.598875 mc (457 x 7875 cycles). If this frequency were used it would create certain design problems at the transmitter. Therefore, 455—the next lower odd multiple of 7875 cycles—was tentatively decided upon. It was found that if this frequency (3.583125 mc) were used it would beat with the sound carrier of 4.5 mc and produce an interference pattern due to the difference frequency of 916,875 cycles. Experimentation proved that this interference would be reduced if the sound carrier were a multiple of half the line frequency. The closest multiple of 7875 cycles to 4.5 mc would be the 572nd. Since 572 x 7875 cycles = 4,504,500 cycles the sound carrier frequency would have to be increased by 4500 cycles, or the field and line frequency would have to be reduced slightly. Since a considerable proportion of TV receivers now in operation use 4.5 mc as the sound frequency, it was decided to reduce the field and line frequencies instead.

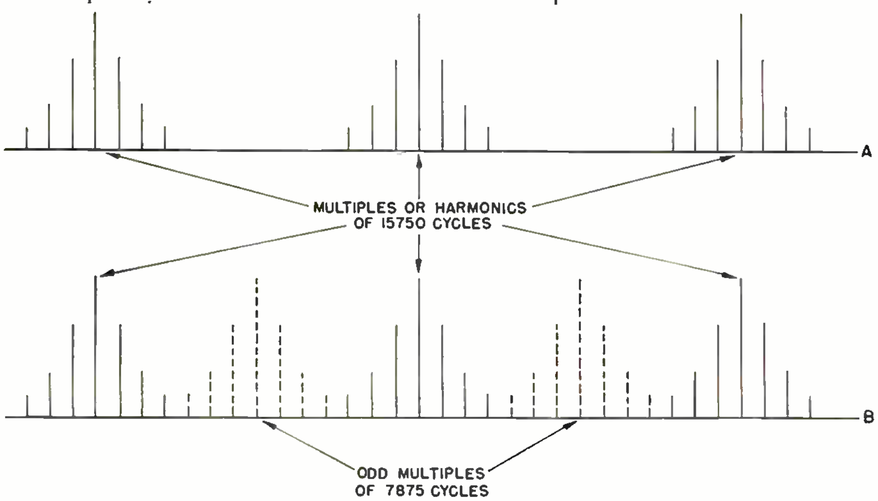

Fig. 2.(A) Space in between harmonics of 15,750 cycles not used during monochrome transmissions. (B) Color signals interleaved between monochrome signals at odd multiples of 7875 cycles

CHANGE IN FIELD AND LINE FREQUENCIES

The line frequency decided upon by NTSC was $\frac{4,500,000}{286}$ cycles or 15734.264 cycles instead of the normal monochrome frequency of 15,750 cycles. As a result of this change in line frequency the field frequency also had to be changed and became $\frac{15734.264}{262.5}$ cycles or 59.94 cycles instead of 60 cycles. The difference between the synchronizing frequencies used for monochrome and those used for color are so small (about 1/10 of one percent) that the synchronizing circuits in TV receivers are not affected by changes from monochrome to color or vice versa.

Since the subcarrier frequency should be an odd multiple of half the line frequency, the change in line frequency also changed the frequency of the color subcarrier. It was previously stated that the color subcarrier frequency should be the 455th harmonic of half the line frequency. Therefore, the subcarrier frequency became 455 x 7875.132 cycles or 3.579545 mc. The following is a list of the frequencies used for monochrome and color transmissions.

MONOCHROME FREQUENCIES

Vertical field frequency 60 cps
Horizontal line frequency 15750 cps (60 cps x 262.5)
Sound carrier frequency 4.5 mc (not divisible by 15750 cps)

COLOR FREQUENCIES

Vertical Field frequency—59.94 cycles
Horizontal line frequency—15734.26 cycles (59.94 cycles x 262.5)
Sound carrier frequency = 4.5 mc (15734.26 cycles x 286)
Chrominance carrier frequency = 3.579545 mc (15734.26 cycles x 227.5)

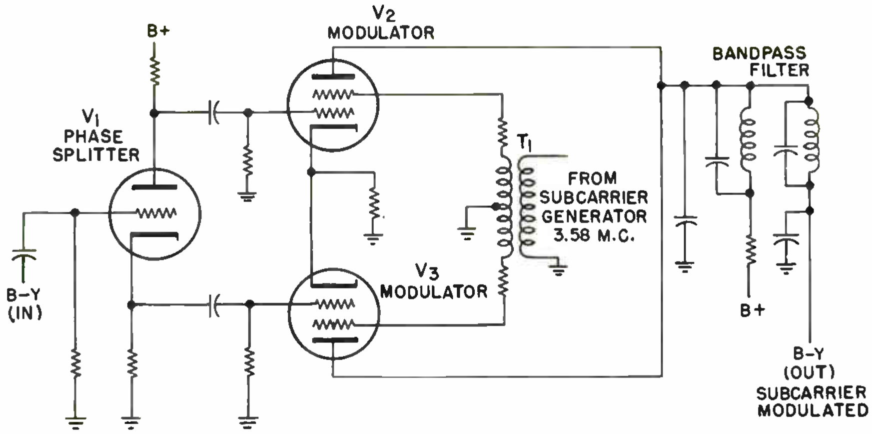

Fig. 4. Simplified balanced modulator circuit.

SUBCARRIER VISIBILITY

The use of an odd multiple of half the line frequency not only permits the color and brightness signals to be interleaved, but also reduces the visibility of the subcarrier frequency particularly on monochrome receivers. Since the color subcarrier is 227.5 x 15734.26 cycles each horizontal line contains 227.5 cycles of the subcarrier frequency. Since there are 525 lines in each frame there would be 525 x 227.5 cycles or 119.437.5 cycles of the subcarrier frequency in each frame. If as an example the first line of a frame starts with a positive half cycle as shown in A of Fig. 3, the first line of the next frame will start with a negative half cycle as shown in B. Therefore the subcarrier frequency on any line will be 180 degrees out of phase with the subcarrier frequency on the same line in the following frame as shown in C. The effect will be almost complete cancellation of any visible indication of the subcarrier frequency. This is due to the half cycle at the end of each frame which causes the phase of the subcarrier frequency to shift 180 degrees on each successive frame.

BALANCED MODULATORS

This subcarrier frequency of 3.579545 mc, which will be shortened to 3.58 mc from now on, is applied to two separate balanced modulator circuits. These balanced modulator circuits prepare the R-Y and B-Y color signals for transmission by modulating the two color signals each upon a subcarrier of the same frequency but with a phase difference of 90 degrees. One reason why balanced modulator circuits are used is to suppress the subcarrier frequency. If the subcarrier were not suppressed both the fundamental subcarrier frequency and the difference frequency produced by the subcarrier and the sound carrier beating together would produce interference patterns which would make the picture unusable. The effect previously illustrated in Fig. 3 would have little value without subcarrier suppression. Even *with* subcarrier suppression some monochrome receiver complaints have been received regarding the 920 kc beat frequency which appears during color programs only. Receivers which are troubled with interference of this type are usually those with a wide i-f band-pass which allows the 3.6 mc color signal to get through. Most of these receivers have a separate sound channel which prevents the viewer from changing the fine tuning control setting so the interference can be tuned out or reduced.

A simplified schematic of a balanced modulator circuit is shown in Fig. 4. The operation of a circuit of this type is simplified by considering the color signal and the subcarrier signal independently. The color signal indicated as B-Y is applied to the grid of V_1. This circuit merely splits the phase of the incoming signal and produces two signals 180 degrees out of phase. A positive going B-Y signal will be duplicated (in phase) at the cathode but will become a negative going signal at the plate due to the normal 180-degree phase shift which occurs between grid and plate signals within a tube. The signals applied to the grids of V_2 and V_3 will be equal in amplitude but opposite in polarity. Since the plates of V_2 and V_3 are tied together the signal voltages developed at one plate will be 180 degrees out of phase with that developed at the other plate. The result will be complete cancellation of the B-Y signal.

If the subcarrier signal is also considered independently it too will not produce any signal at the output. Since the 3.58 mc subcarrier signal is applied to transformer T_1, which has a center tapped secondary winding, the signals applied to the suppressor grids of V_2 and V_3 will be 180 degrees out of phase with each other. The signal voltage produced in the plate circuit will also be of opposite polarity and will therefore cancel.

When both the B-Y and the 3.58 mc subcarrier frequencies are applied to V_2 and V_3 the action of each tube is similar to an ordinary *mixer* tube. Several frequencies are therefore present at the plate of each tube including the B-Y signal, the subcarrier signal and sidebands which are produced when the two signals are combined. Since both the B-Y signal and the subcarrier signal on V_2 would be 180 degrees out of phase with the same signals on V_3 they would be practically cancelled. The sideband frequencies would not be cancelled but would represent the subcarrier frequency, modulated by both the amplitude and phase of the B-Y signal. The balanced modulator circuit actually performs two functions. First it suppresses the individual B-Y and subcarrier signals and second, it produces an output signal, but *only* when both input signals are present. The output signal goes through a bandpass filter which is designed to pass only frequencies between 3.0 and 4.2 mc. These frequencies will fall approximately within the response curve shown for the B-Y signal in Fig. 1. The NTSC established specific limits for the color signals. These limits are not accurately reproduced in Fig. 1 because it is not drawn to scale.

The R-Y signal is applied to a circuit very similar to Fig. 4. The input from the subcarrier generator, however, is not applied directly to the modulator. First it goes through a circuit which shifts its phase by 90 degrees as shown in the Fig. 5 block diagram. The output signal from the R-Y balanced modulators is basically similar to the B-Y output signal except that the R-Y output signal is produced by combining the R-Y signal with the *same* subcarrier which has been shifted in phase by 90 degrees. Inasmuch as the two color signals are always 90 degrees out of phase with each other, this type of modulation is sometimes called quadrature modulation. The bandpass filter in the output circuit R-Y balanced modulator is designed to pass frequencies between 2.0 and 4.2 mc and produce the wider response curve shown for the R-Y signal in Fig. 1.

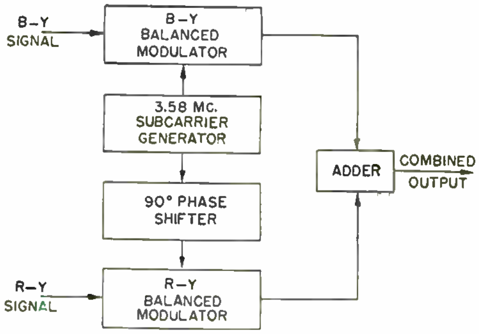

Fig. 5. Block diagram of circuits which make the color signals suitable for transmission.

The two color signals which are 90 degrees out of phase with each other are combined in the adder circuit. The output of this adder circuit is the complete chrominance signal.

(To be continued)

BENCH NOTES

Contributions to this column are solicited. For each question, short-cut or chronic-trouble note selected for publication, you will receive $10.00 worth of electronic tubes. In the event of duplicate or similar items, selection will be made by the editor and his decision will be final. The Company shall have the right without obligation beyond the above to publish and use any suggestion submitted to this column. Send contributions to The Editor, Techni-talk, Tube Department, General Electric Company, Schenectady 5, N. Y.

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1. Do not use a polish that has an oil or wax base, likewise, any substance of a petroleum base.
2. For removing light scratches or abrasions, go over entire area with 4/0 grade steel wool using even strokes in the long dimension. When scratches or abrasions are removed, polish the surface by rubbing with a moist soft cloth and rotten-stone. Use water as a vehicle.

The above will produce an acceptable luster, however, a light buffing with a clean lambs-wool bonnet attachment on an electric drill will improve it somewhat. A certain amount of caution will have to be used because the finish can be burned and completely ruined if too much pressure is applied to an area for more than a few seconds. It must be remembered that the original mold sheen cannot be reproduced.

What's new!

"WHY A 6SN7-GTB"

The General Electric Company recently registered with RETMA the Type 6SN7-GTB. The tube is electrically and mechanically interchangeable in all television sets using either the 6SN7-GT or the 6SN7-GTA. The only difference between the 6SN7-GTA and the 6SN7-GTB is that the heater warm-up time of the 6SN7-GTB is being controlled for series string television sets.

There is now available a complete line of tubes utilizing 600-ma heaters for series string sets. This line of tubes allows the set designer to build a series string television set with only one string of tubes in series with the television picture tube. The television picture tubes have always had a 600-ma heater.

There are two potential sources of tube failure in a series string television set. The first one of these is heater burn-out due to voltage surges immediately after the set has been turned on. The second potential source of failure is heater-cathode breakdown since series string sets utilizing voltage doubler power supplies impose severe heater-cathode voltages on some tubes in the series string. Heater burn-outs due to voltage surges during warm-up have been controlled in this line of tubes by actually measuring the change in resistance of the heater during the warm-up time and specifying it as a controlled test for the tubes. The change in resistance of tungsten wire which is used for the heater is quite large. The nominal operating voltages of the tungsten heater is about 1100°C. The resistance of the wire when cold is only about 15% of the resistance of the wire when it is hot. A tube having a normal rating of 6.3 V and 600-ma has a heater resistance of 10.5 ohms while hot and only 1.58 ohms when cold. The tubes for series string television sets have controls on the rate of change of resistance of the heater during the warm-up time so that all tubes warm up uniformly and thus prevent high voltage surges on individual tubes in a series string. The controls are such that with a random selection of tubes in a given series string no individual tube will see more than one and one-half times its rated voltage during warm-up.

The second problem concerning series string television sets is one of high heater to cathode voltage. Depending upon the type of power supply used in a series string television set, the heater-cathode voltage can get as high as 300 V peak which is considerably over the normal rating for receiving type tubes. Tubes which have been designed for this series string type of service are rated and life tested in accordance with the requirements of series string television sets using various voltage doubler type of supplies. It is therefore essential that the serviceman replace tubes that are specified for this type of service. Thus, the 6SN7-GTA becomes a 6SN7-GTB and it is controlled for:

(1) Heater warmup time
(2) Heater-cathode voltages compatible with series string usage.

The 6SN7-GTB can be used as a replacement for a 6SN7-GTA. There are only a few other series string types which can be substituted for prototypes. Those series string types which require the same heater voltage, indicated by the use of the same first digit in the type number, can be substituted for prototypes. Examples of these tube types are the 6S4-A, 12AX4-GTA, 12B4-A, 12BH7-A, 12BY7-A and the 6SN7-GTB previously mentioned. Tubes which require different heater voltages cannot be substituted.

Listed below are the tubes which are currently available for service in series string television sets:

Prototype	Tubes for Series String
6AL5	3AL5
6AQ5	5AQ5
6AU6	3AU6
6AV6	3AV6
6BA6	3BA6
6BC5	3BC5
6BE6	3BE6
6BK5	12BK5
6BK7-A	5BK7-A
6BN6	3BN6
6BQ6-GA	12BQ6-GA
6BQ7-A	4BQ7-A
6BZ7	4BZ7
6CB6	3CB6
6CD6-G	25CD6-GA
6CS6	3CS6
6J6	5J6
6S4	6S4-A
6SN7-GTA	6SN7-GTB
6T8	5T8
6U8	5U8
6V6-GT	5V6-GT
6W6-GT	12W6-GT
12AU7	7AU7
12AX4-GT	12AX4-GTA
12B4	12B4-A
12BH7	12BH7-A
12BY7	12BY7-A
25L6-GT	12L6-GT

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