Facsimile Modulator Tube

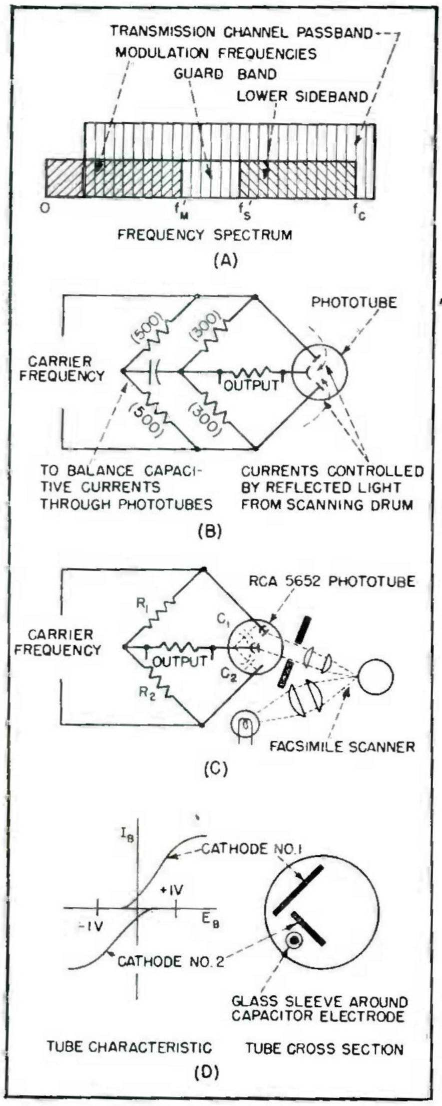

FIG. 1—**Basic considerations in design of bridge modulator for fascimile**

By J. R. SHONNARD

Times Facsimile Corp.
New York, N. Y.

HIGH RESOLUTION facsimile signals are transmitted over existing communication facilities by amplitude-modulated low-frequency carriers. A new type phototube and bridge modulator have been developed that enable light from the facsimile scanner to produce the modulation directly without generating frequencies that have to be eliminated by costly filters. The tube and circuit may simplify other systems in a similar manner.

Facsimile Transmission

Before describing the phototube and its action in the circuit, it is best to review the modulation problems that lead to its development. In many communication systems, facsimile being a typical example, the lowest modulation frequency is zero cps, corresponding in this case to a picture area of uniform density. The highest frequency is limited by what can be transmitted by the channel. Modulation currents as such cannot be transmitted over existing facilities because they are essentially interrupted d-c. To transmit them without introducing excessive distortion the channel would have to be polarized from transmitter to recorder thus requiring d-c amplifiers.

The solution to the problem has been to transmit the signal as an amplitude-modulated low-frequency carrier of frequency f_c. Under such condition the highest modulating frequency f_M' is limited to half the carrier frequency, assuming that filters with ideal cutoffs are available. Therefore the highest possible carrier should be used. In practice, the upper frequency limit is determined by the top of the channel passband. The carrier frequency is thus selected near this limit. Only the lower sideband of the amplitude-modulated carrier can then be transmitted, but this is all that is necessary for faithful reproduction and provides an efficient way to use the available channel. The manner in which these frequencies occupy the channel spectrum is shown in Fig. 1A.

The modulation frequencies f_M produce lower sideband frequencies f_S extending from the carrier f_C to the lowest sideband frequency $f_S' = f_C - f_M'$. When $f_M' = f_C/2$, $f_S' = f_M'$. If a higher modulation frequency is used the modulation band overlaps the lower sideband producing extraneous frequencies. Under such conditions filters cannot be used to prevent modulation frequencies from reaching the transmission circuit. If $f_S' = f_M'$, ideal filters could separate the modulation and sidebands and 50 percent of the transmission band would be used. Actually sufficient guard band must be left between modulation and sideband frequencies so that realizable filters can be used. If filters that do not have such sharp cutoffs as to introduce transient distortion are employed, the maximum use ratio of the channel is only 30 percent.

Phototube Modulator

The conventional type phototube bridge modulator shown in Fig. 1B produces both the modulation frequencies contained in the impinging light beam and the sideband frequencies of the modulated carrier in its output. The circuit is balanced for reactive and resistive currents. Light on the phototube upsets the resistive balance to produce the modulation.

When the RCA 5652 phototube, which has been designed for this service, is used, the output contains only the modulated carrier and sidebands. The signal can be connected directly to a conventional amplifier that is reasonably flat over its passband; filters are unnecessary. The phototube has two flat cathodes arranged at approximately right angles to each other. When both plates are illuminated, one acts as a cathode and the other as an anode, depending on the polarity of the

Phototube having two plates each acting alternately as cathode and anode simplifies bridge modulator. Because tube conducts alternately in one direction and then in the other, only desired modulated carrier and side bands appear across the output

potential applied between them. If the applied potential is alternating, equal current pulses flow in both directions with equal light on both plates. The average current is then zero. Even a flash of light for the duration of one cycle of the carrier causes equal but opposite pulses to flow so that the effective current remains zero up to modulating frequencies of half the carrier frequency. Contrasted to this action, the current flow in a conventional phototube in a modulator circuit is unidirectional.

As used in the modulator, the new phototube is a variable impedance, the two cathodes being connected as an arm of an a-c bridge. Capacitive current is balanced, preferably by an electrode built into the phototube and completely covered with a dielectric. The capacitance between this electrode and one cathode is made approximately equal to the capacitance between cathodes.

For modulation by this tube the bridge circuit can be arranged as in Fig. 1C. If no light reaches the tube and $R_1 = R_2$ and $C_1 = C_2$, there is no voltage output. As reflected light reaches the phototube, conduction takes place in the direction governed by the polarity of the carrier. Both electrodes are photoelectric and therefore act alternately as cathodes and as anodes.

The amplitude of the applied carrier is limited by saturation of the cathode current in this circuit. The phototube operates on the linear portion of its characteristic curve, shown in Fig. 1D, for a given range of light values. In the case of high definition facsimile the maximum light is in the order of 4×10^{-4} lumens. The elemental area of illumination at the scanning drum is about 5×10^{-5} square inches. The carrier potential applied to the bridge is about 0.7 rms volt. If the bridge is balanced with the light source off, when the light is turned on the output voltage will be undistorted modulated carrier proportional to the instantaneous light intensity reflected from the rotating scanning drum; only carrier and sidebands will be present.

Operating Circuit and Tests

For convenience and ease of adjustment the circuit that is used has balancing controls. In addition, a diffusing plate is placed over the aperture to overcome two difficulties. First, a sharply focused image can cause uneven illumination of the two cathodes and thus produce occasional d-c keying components in the output. Second, the light beam passing through the aperture covers too small an area on the photocathodes for ease of adjustment when balancing the bridge to eliminate the modulation frequencies from the output, unless the optical system is very long. The diffusing plate defocuses the beam without sacrificing resolving power.

In operation, the output voltage varies from a maximum between 0.005 and 0.010 rms volt to a minimum controlled by the noise from the balanced bridge with the light off. The noise level of the bridge and the first stage of the amplifier is equivalent to 25 to 50 microvolts at the grid of the first stage. The load resistor, which also serves as the grid resistor of the first amplifier tube, can be from 1 to 20 megohms depending on the compromise that must be made between high sensitivity and stability against humidity, stray fields and input noise. The phototube noise does not seem to be a problem. The useful voltage ratio for light variations is therefore from 40 to 50 db.

When the scanner observes a 1.6-reflection density photographic black, the output rises about 10 db above the noise level. This level determines the minimum useful signal. When the scanner observes a bright white, the output rises an additional 30 to 35 db. However, such a range is beyond the capabilities of an average transmission channel. Therefore, after amplification, the signal is compressed to a range of about 20 db, within the limits of most channels.

Resolving power of any equipment with a given carrier frequency can be determined roughly by reducing the size of print being transmitted until the copy reproduced at the receiver is just illegible, assuming the receiver to be linear above the carrier frequency. A better but more complicated method is to select a type face and size that has a line width greater than is necessary to block light to the phototube. It is then certain that full interruption of the light to the phototube will be produced regardless of scanning velocity. Increasing the scanning velocity at both transmitter and receiver with a given carrier frequency will determine the maximum resolving power, and therefore the maximum usable modulation frequency for a given system. With the new phototube, 50-percent utilization of the channel can be realized and thus good resolution can be obtained.