CRT DATA

T5191

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CRT Engineering

In a 519 high frequency oscilloscope, the vertical deflection characteristics of the T5191 cathode-ray tube are important limitations of the instrument. For some applications, one may wish to change the beam voltage through the deflection assembly in order to maximize one electrical characteristic at the sacrifice of another. The characteristics that follow in this text are:

1. Relative Deflection Sensitivity versus Frequency.
2. Signal Velocity versus Frequency.
3. Insertion Power Loss Ratio.
4. Voltage Standing Wave Ratio.
5. Transient Response to a Unit Step Function.

These are average characteristics of some typical cathode-ray tubes and should not be interpreted as applying to a specific tube.

The characteristic impedance, Z_o, at low frequency is 125 ohms. The T5191 Vertical Deflection Assembly diagram with the stripline, lower deflection plate, tuning screws, stripline support, and shield is illustrated in Figure 1.

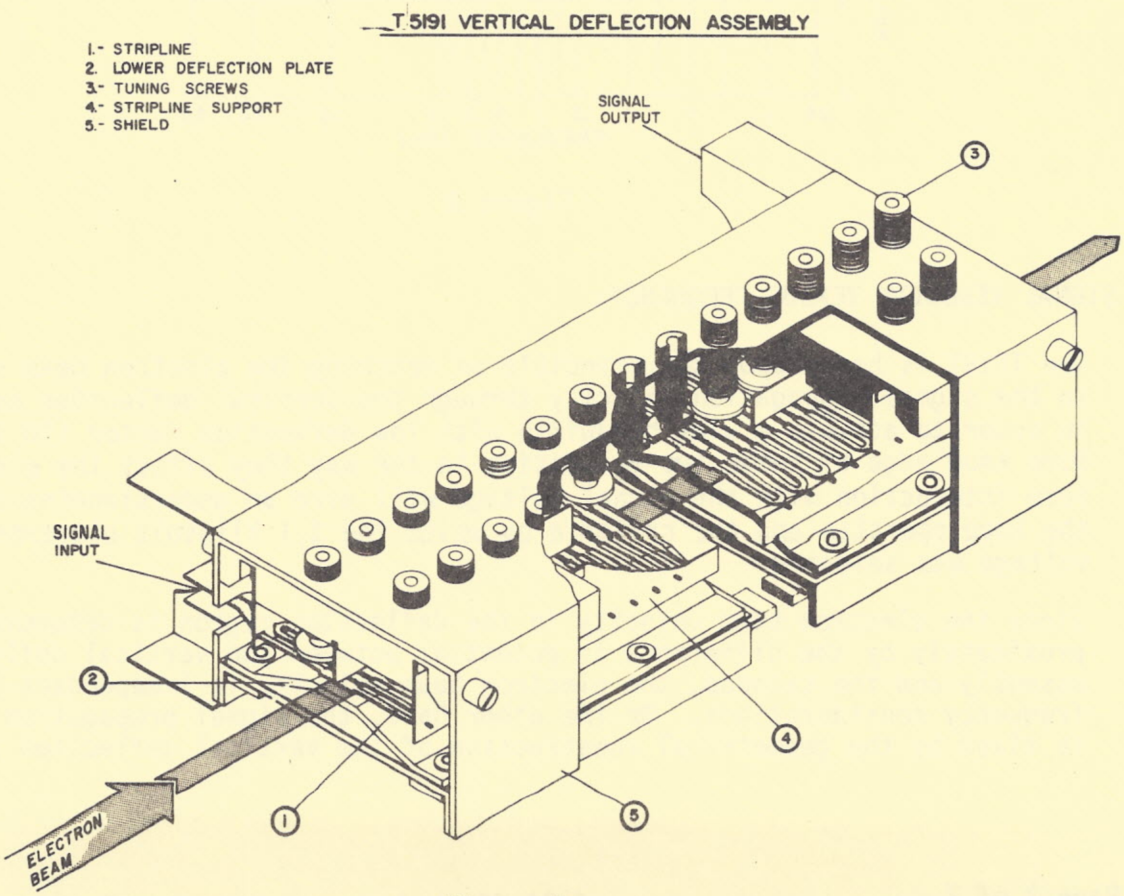

Figure 1

RELATIVE DEFLECTION SENSITIVITY VERSUS FREQUENCY:

If a sine wave of constant amplitude is fed into the CRT deflection assembly, the peak-to-peak amplitude of the displayed sine wave decreases with an increase in frequency. The graph shows the relative deflection sensitivity as a function of frequency for various velocities of the electron beam passing through the deflection assembly. The greatest bandwidth for a T5191 occurs between 3.0 to 3.5 kilovolts. See Figure 2.

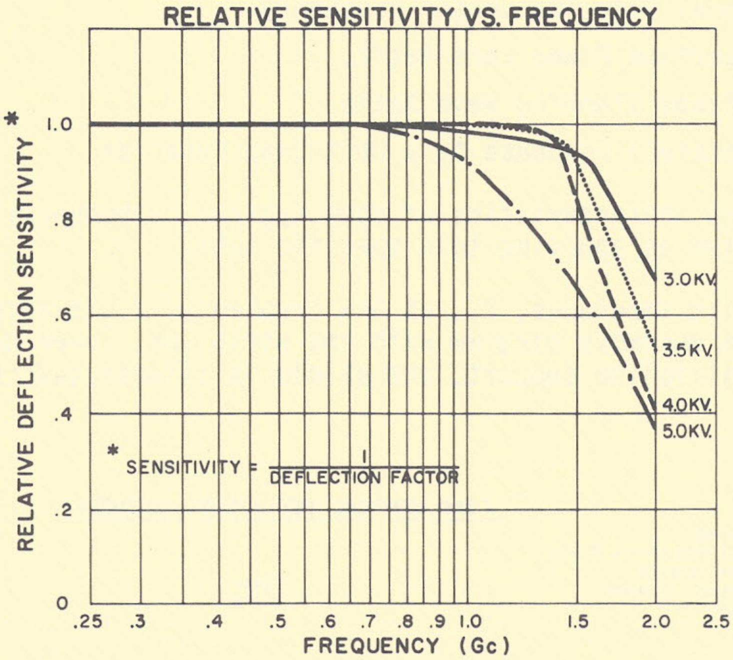

Figure 2

SIGNAL VELOCITY VERSUS FREQUENCY:

The T5191 is based upon the principle of matching the electron beam velocity to the signal propagation velocity through the vertical deflection assembly in order to achieve a wide bandwidth with low deflection factor (10 V/cm). Some knowledge of these two velocities in the way they affect the electron beam interaction with the signal voltage will give an understanding of how the tube operates and the criteria by which the 4.1 kilovolt electron beam voltage was selected.

Since the electron beam velocity in the deflection region is determined approximately by the difference in potential between the vertical deflection assembly and the cathode, the electron beam velocity is independent of any frequency considerations. On the other hand, the signal propagation velocity is fixed by the geometrical construction of the vertical deflection assembly and has a velocity which diminishes at the higher frequencies--see Figure 3, Signal Velocity versus Frequency. The two velocities can be the same over only a limited frequency range.

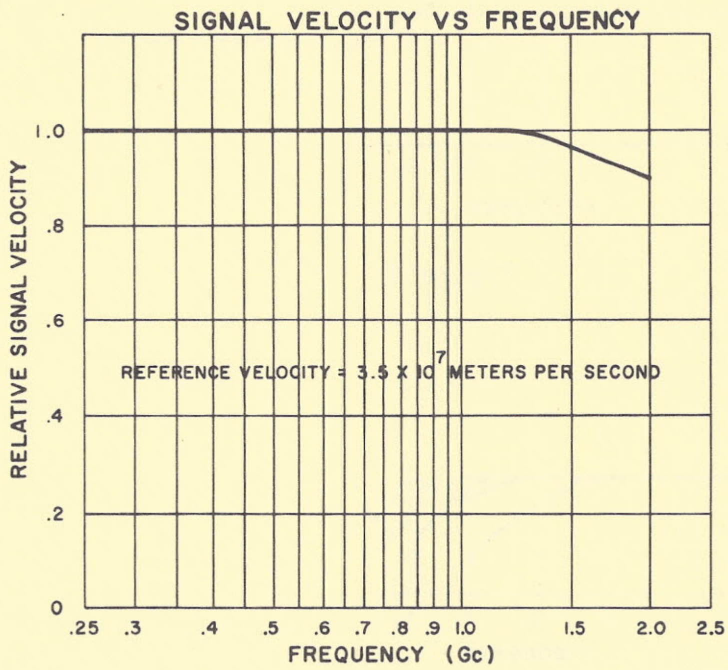

Figure 3

For signals with wavelengths that are short enough to be affected by transit time considerations, the velocity mismatch can be important. If a single electron is considered moving through the vertical deflection assembly with the same velocity as the signal, this electron will always be affected by the same point of the signal throughout its transit and will experience the maximum electron beam deflection possible. An electron with a velocity other than that of the signal will be affected by various portions of the signal (the extent depending upon the amount of velocity mismatch) and electron beam deflection is reduced. The effect of the velocity mismatch can be discussed in the following way for four possible cases, where v_s and v_e are respectively the signal and electron velocities:

(1) v_e greater than v_s; (2) v_e equal to v_s; (3) v_e slightly less than v_s; and (4) v_e much less than v_s. Velocity versus Frequency curves and Amplitude

versus Frequency curves are sketched for the four conditions in the following graphs.

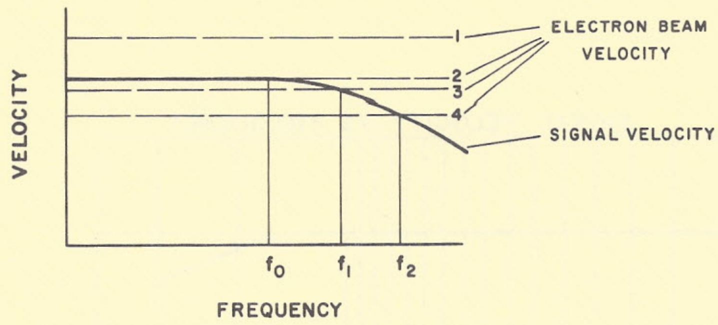

Figure 4

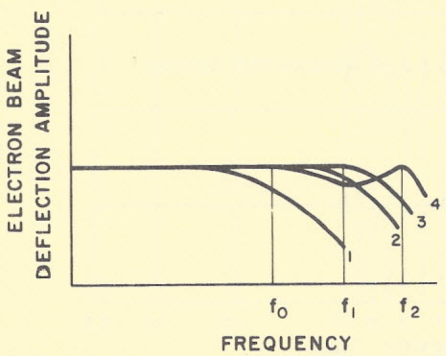

Figure 5

(1) For v_e greater than v_s, a velocity mismatch occurs over the entire frequency spectrum with attenuation of electron beam deflection beginning at a fairly low frequency; (2) for v_e equal to v_s, the velocity mismatch begins at f_o, where the signal velocity curve begins to droop; (3) for v_e a little less than v_s, a velocity match occurs at a frequency a little greater than f_o, such as f_1; and the electron beam deflection is the same at this frequency as for a dc voltage. The electron beam deflection attenuation which occurs in the region between f_o and f_1 is small enough to be neglected; (4) for v_e much less than v_s, the velocity match occurs at a still higher frequency, f_2. Electron beam deflection attenuation is now noticeable both below and above f_2.

For the T5191, the cut-off characteristics of the vertical deflection assembly stripline beyond 1.5 gigahertz masks such peaks as f_2. Note in the Figure 2, 3 kV curve, that no indication of an f_2 peak can be observed. Electron beam deflection amplitude response can be maximized by making v_e a little less than v_s (case 3) but such a choice is normally not desirable. An explanation of why this is not desirable is simplified if the discussion is now shifted from frequency response to transient response. If, in traveling throught the deflection assembly stripline, the high frequency components of a signal arrive later than lower frequency components, an overshoot develops because the high frequency components which should be effective in the leading edge are delayed and stacked up on top of the front corner. Examination of Figure 3, Signal Velocity Curve, shows that the high frequency components will have a propagation velocity less than the lower frequency components.

Since the signal velocity curve plotted in Figure 3 is a typical curve for the T5191 vertical deflection assembly, we can conclude that a very noticeable overshoot would be observed in the displayed transient response unless some compensation is made. Compensation is possible by deliberately choosing a mismatch between v_e and v_s. If we make v_e greater than v_s, (Case 1), the electron moving through the vertical deflection assembly will approximately keep in step with the low frequency components of the transient signal, but with respect to the electron, the high frequency components will gradually fall behind. We have stated that maximum deflection of the electron will occur when the signal velocity equals the electron velocity. If the high frequency components of the signal lag (fall behind), the electron beam will be deflected somewhat less for high frequencies than for low frequencies and we have obtained some compensation for the nonuniform propagation velocity of the signal in the vertical deflection assembly. In the T5191, a compromise is necessary. That compromise seems best accomplished when the cathode to vertical deflection assembly potential of 4.1 KV is used, which gives an overshoot of less than 7%.

INSERTION POWER LOSS VERSUS FREQUENCY:

In some instances, we may want to use the signal after it has passed through the CRT, instead of dissipating the signal energy in a resistor. An indication of the power response of the CRT as a two-terminal pair network can be obtained from the curve of insertion power loss ratio. The insertion power loss ratio for a T5191 is the ratio of the power delivered to the output termination through the CRT to the power that would be delivered to the load if the generator and the load were tied together.

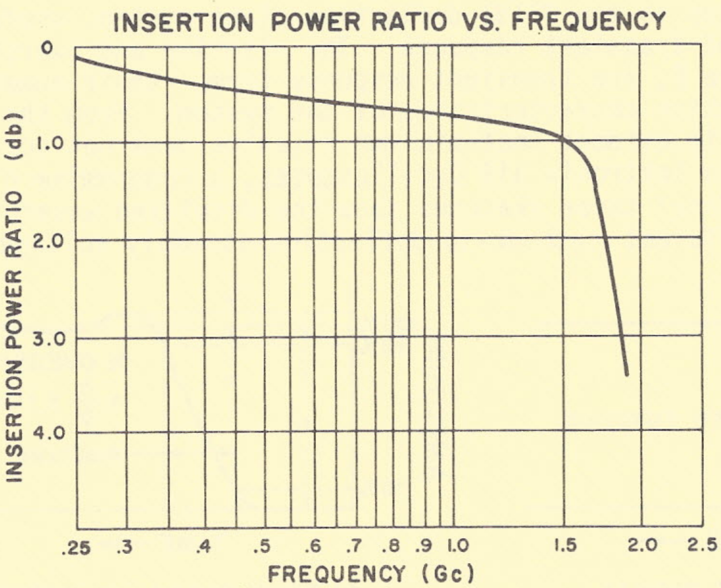

Figure 6

VOLTAGE STANDING WAVE RATIO:

The existence of a standing wave is evidence of discontinuities along the transmission line and its termination. The effect of these discontinuities is indicated by the Voltage Standing Wave Ratio (VSWR). In order to measure the VSWR of the T5191, a special 125 ohm slotted line with a residual VSWR of less than 1.03 and a standard Tektronix T125 termination was used.

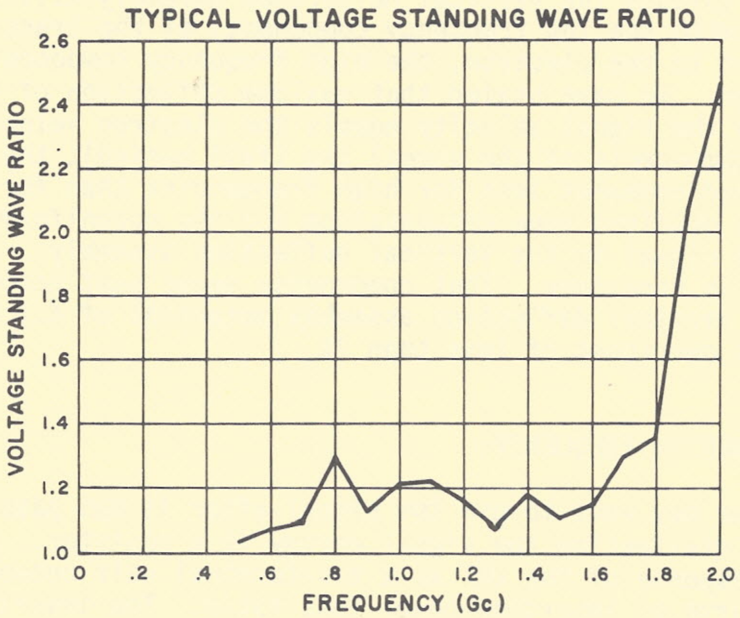

Figure 7

TRANSIENT RESPONSE TO A UNIT STEP FUNCTION:

If we apply a unit step to the T5191 deflection plate system, useful output appears as a displayed transient response. The risetime and overshoot, illustrated below in Figure 8, are transient response terms--their numerical values indicate the transmission characteristics of the system. From the curves of Figures 9 and 10, it is evident that minimum risetime does not correspond with minimum overshoot. In Tektronix 519 Oscilloscopes, a compromise of 4.1 kilovolts is used. The final three sketches show the displayed waveforms corresponding to three different cathode-to-deflection-assembly voltage differences.

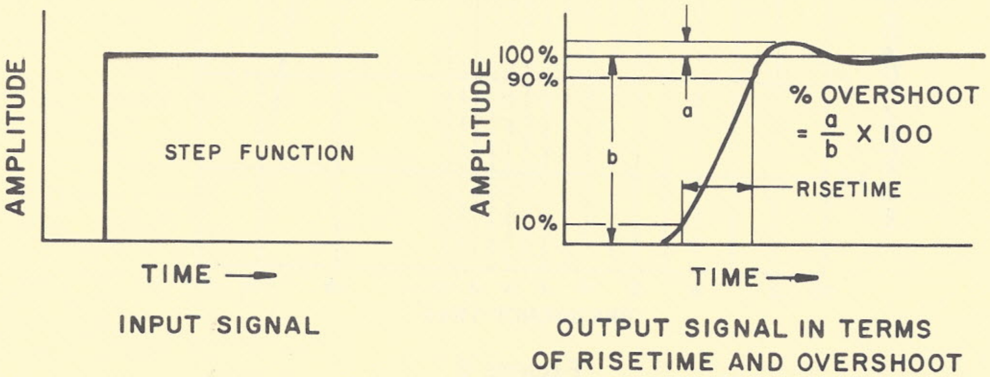

Figure 8

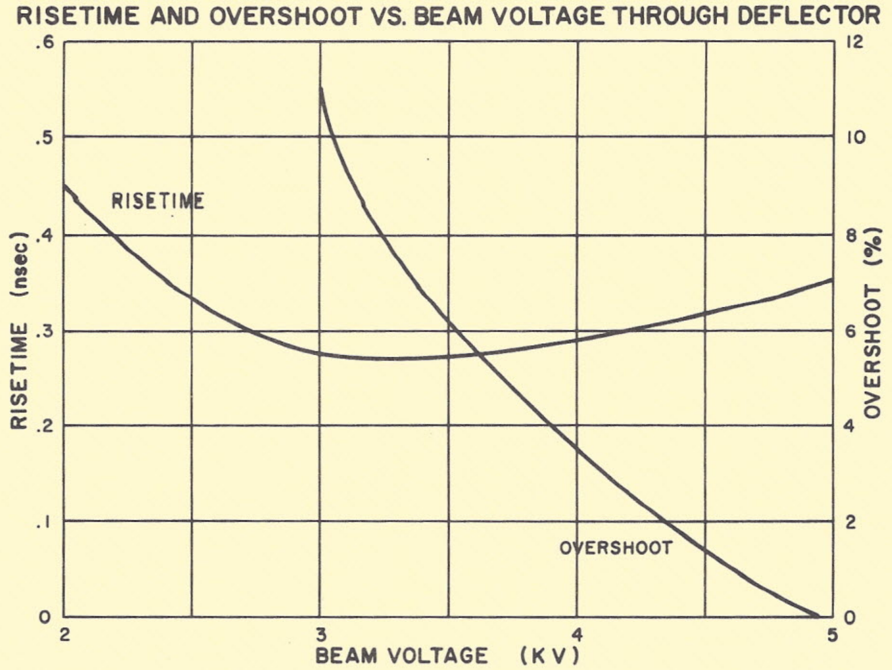

Figure 9

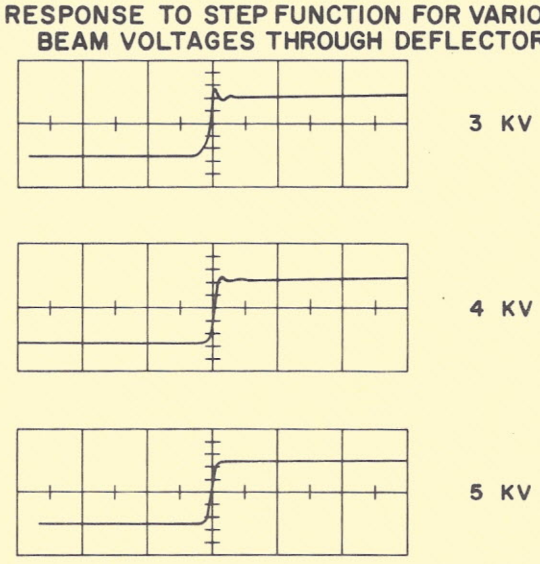

Figure 10

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Product Technical Information