J. F. GOLDING

SWEPT FREQUENCY DIAGNOSTIC TECHNIQUES FOR COLOUR TELEVISION TRANSMISSION NETWORKS

INTRODUCTION

For the purposes of this article, a transmission network is defined as the whole or any part of the overall link between the television camera tube and the picture c.r.t. The measurement techniques, however, apply only to networks in which the input and the output signal are at video frequency.

The performance requirements of a colour signal transmission network are basically similar to those of a monochrome network, except that the tolerances on the flatness of its frequency response characteristic and frequency phase characteristic are very much closer. Many of the standard measurements on colour circuits are, therefore, refinements of methods originally devised for monochrome circuits; and, for overall performance assessment, the maximum information is obtainable by the use of special test signals – such as sine-squared-pulse and bar and the various grey-scale waveforms – which simulate the effects of actual picture signals.

These test signals normally comprise special waveform components for measurement of the network's relative performance at the colour subcarrier frequency and at the lower video frequencies, so facilitating accurate measurement of comparative gain and delay at the two parts of the video spectrum where they are most critical.

In practice variations of phase with frequency are normally directly related to variations in gain; and, for diagnostic and initial design purposes, analysis of the response characteristic over the whole video spectrum is often more revealing than the information obtained from the use of special test waveforms. Such analysis is usually made with a frequency sweep generator in conjunction with a suitable oscilloscope.

DIRECT MEASUREMENTS

The M.I. TF2361 Sweep Generator, when used with its Video Frequency plug-in sweep unit, delivers an output signal the level of which remains constant within ±0·1dB over the total sweep range of 25kHz to 30MHz. When the instrument is used with the detector supplied, and its attenuator set for 1V output, the overall detected flatness is claimed to be better than ±0·05dB over the same frequency range. With this instrument, therefore, it is possible to display the response characteristic of an active or passive network on a suitable oscilloscope, and discriminate departures from flatness of small fractions of a decibel. The block diagram of an electrical arrangement is shown in figure 1.

In order to display these small variations in net-

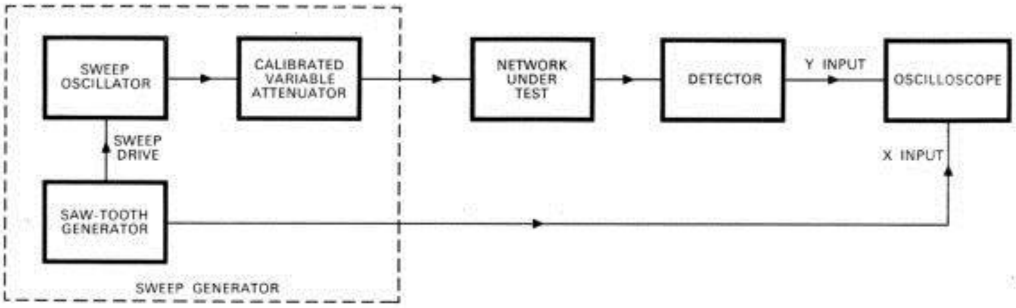


Fig.1 The basic arrangement for response characteristic measurement with a sweep generator and oscilloscope.

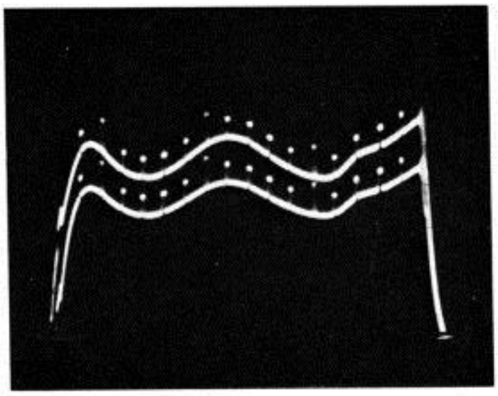


Fig.2 Dual displays separated by 1dB obtained by use of the TF2361 Sweep Generator's fine level control on alternate sweeps. The frequency markers are generated within the sweep generator and superimposed on the detected signal.

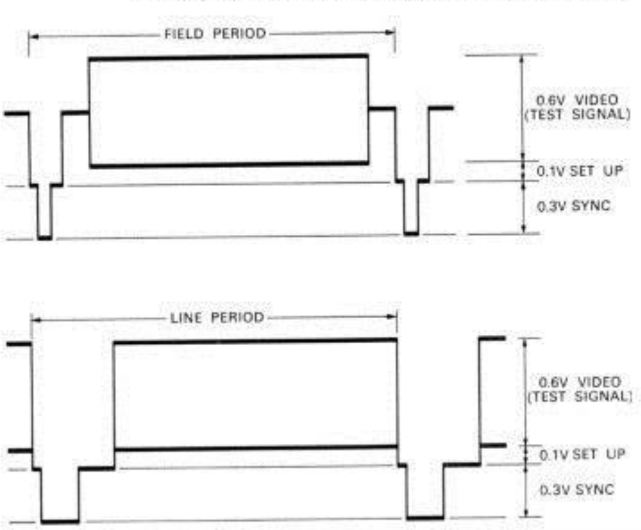


Fig.3 Composite waveform including blanking and sync pulses. The sweep drive would normally be at field rate for tests using this waveform.

work response the oscilloscope used must have adequate gain and also adequate windowing ability; i.e, it must be possible to apply to the input of the Y amplifier a shift voltage of approximately 10 times the deflection voltage for 1dB signal variation without undesirable effects. Assuming that 2cm deflection for 1dB change in detected signal voltage give sufficient reading discrimination, the d.c shift required would be equivalent to 20cm deflection – or rather more than three times a 6cm vertical viewing aperture.

The windowing requirement can present difficulty with some oscilloscopes, so that it becomes necessary to reduce the effective Y gain, with consequent reduction in discrimination.

Below 1dB the decibel scale becomes virtually linear; and, once the deflection change for 1dB change in signal level has been established, the oscilloscope's voltage calibration could be used for interpretation. For example, if 1dB were equivalent to 2cm, 0·1dB would be equivalent to 2mm. The usual way of establishing this 1dB deflection change is by a slide-back method, using either a 1dB attenuator pad or the output attenuator of the sweep generator.

In the M.I Sweep Generator, however, the automatic level control (a.l.c) system is utilized to provide a very useful calibration facility. By adjustment of a calibrated control, the a.l.c reference level can be varied up to ±1dB, for fine control of the signal level. Furthermore the instrument can be switched so that the fine level control is effective on every sweep or on alternate sweeps only. In this second condition the display consists of two facsimiles of the response characteristic separated by a vertical distance corresponding to the setting of the fine level control. Figure 2 shows the appearance of such a display.

By setting the fine control to give a separation of 1dB, the oscilloscope sensitivity can easily be adjusted to produce a conveniently divisible interval. Alternatively, the fine control may be used to determine the relative response of the network under test at any two frequencies on the sweep.

INTRODUCING BLANKING AND SYNCS

The simple arrangement of figure 1 is unsuitable for many of the active networks used in television transmission systems because they contain d.c restoring circuits or blanking-level clamps. Such networks require a test signal of the form shown diagrammatically in figure 3, in which the a.c signal is superimposed on a full-line pedestal and is suppressed during the blanking period. This type of test waveform is easily produced by passing the frequency swept signal through a suitable mixing circuit; and the Blanking and Sync Mixer TF2908 has been specially designed as a complementary unit to the Sweep Generator for television applications.

Use of the waveform of figure 3, however, introduces a new source of error into the measurement system. The normal type of a.c coupled peak-reading detector (Fig. 4) is certainly insensitive to the d.c component of the signal resulting from the pedestal, but each blanking pulse discharges the series capacitor, which recharges through the relatively high load resistance to produce a waveform across the shunt diode of the form shown in figure 5. The mean d.c level of this waveform is

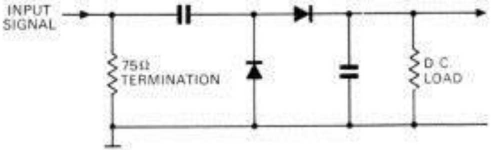


Fig.4 Functional diagram of simple detector suitable for the arrangement in figure 1.

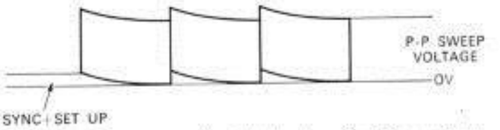


Fig.5 Waveform across shunt diode when blanking and sync are applied.

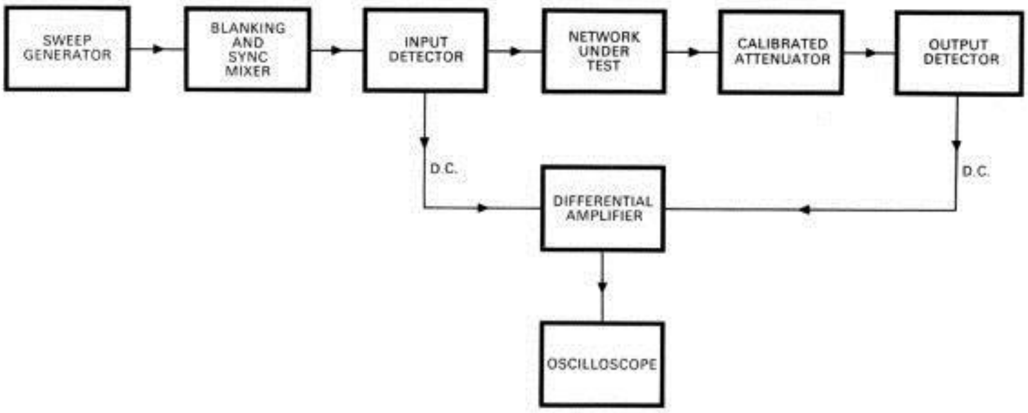


Fig.6 Basic electrical arrangement for differential tests of network response.

significantly higher than that of the detected sine wave alone, so that variations in network response with frequency is masked by detection of the blanking waveform.

This difficulty is completely overcome by also applying the blanking pulse to the earthy end of the shunt diode, which then remains in the non-conducting condition throughout the blanking period, and the error is obviated.

DIFFERENTIAL MEASUREMENT

The Blanking and Sync Mixer's frequency response characteristic is flat within 0·3dB from 25kHz to 20MHz and within 0·2dB up to 10MHz. Nevertheless, when the very small level variations due to the mixer are added to those of the Sweep Generator itself, the resulting uncertainty in the flatness of the test input signal begins to be a significant proportion of the total permitted variation. The solution to this difficulty is found in the differential method of measurement, where both the input and the output voltage are monitored by the use of matched detectors.

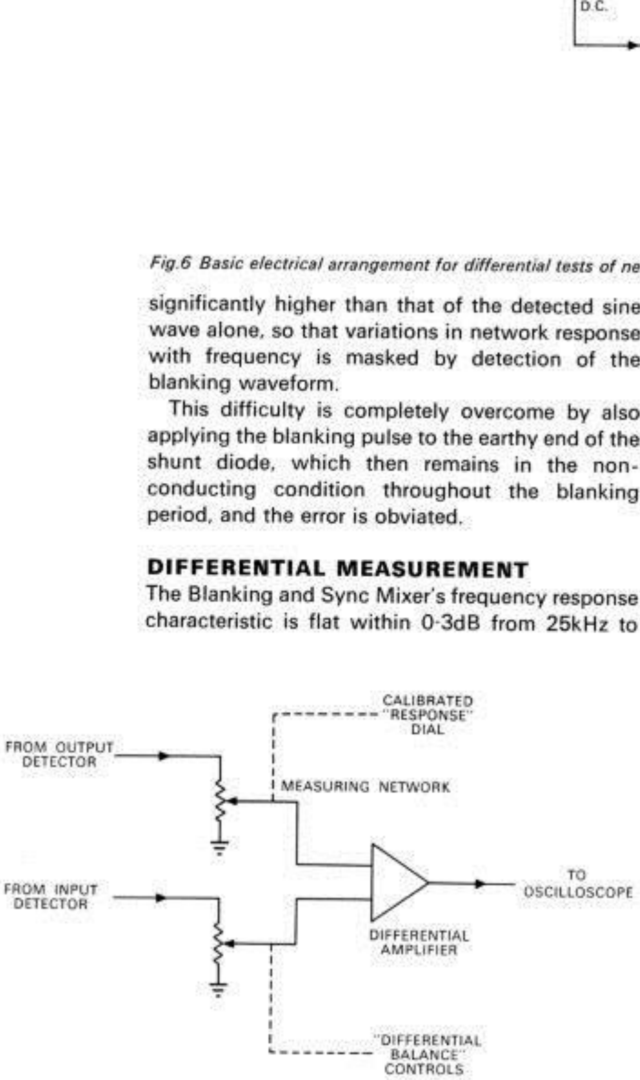


Fig.7 Simplified diagram of the measuring circuit of the Differential Probes Unit.

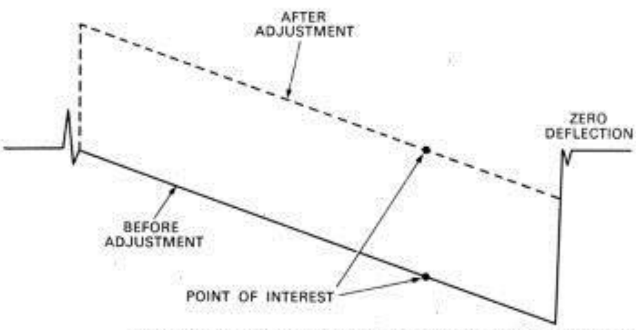


Fig.8 Adjustment of the Response control for slideback method of measuring response at any particular frequency.

Figure 6 shows the basic electrical arrangement for making differential response tests on a network having a gain greater than unity. The overall gain of the signal path is reduced to unity at the reference frequency by a calibrated attenuator, having a flat response characteristic, in cascade with the amplifier under test. The d.c outputs from the detectors are fed to the respective inputs of a differential amplifier, which delivers an output proportional to the difference between its two input voltages. This output is fed to the Y input terminal of the oscilloscope.

At the reference frequency, where the two detected voltages are equal, the Y input signal will be zero, and at other frequencies the spot will be deflected above or below the zero line as the response of the network under test varies. The differential method thus offers the second advantage that a large windowing capability is not required of the oscilloscope, which can, therefore, usually be used at a higher gain setting than for measurements using a single detector.

The Differential Probes Unit TF2907 basically comprises the necessary circuits for differential measurements of this kind. It includes the differential amplifier and calibrated attenuator, together with the means of applying blanking to the detectors.

THE MEASURING CIRCUIT

In the basic differential system the response at any frequency could be measured by adjusting the series attenuator to bring the deflection corresponding to the frequency of interest to the zero-input position on the oscilloscope's c.r.t screen. Provided the attenuator is adjustable in sufficiently small increments this method is generally satis-

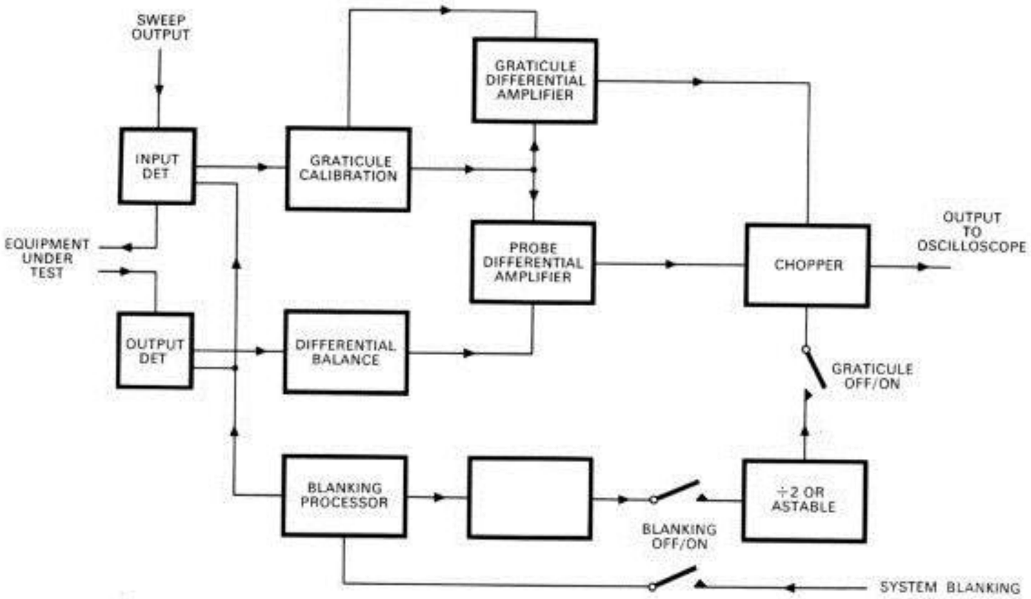


Fig.9(a) Use of a second differential amplifier for provision of a calibrated graticule line on the display.

factory. It has the slight disadvantage that when the attenuator is connected at the input of the network under test, the test level is effectively varied by adjustment of the attenuation. Furthermore, this method cannot be used when the gain of the device under test is close to unity at the reference frequency.

In the TF2907 a separate measuring system is provided. This consists primarily of a simple continuously variable attenuator network between the input detector and the appropriate input of the differential amplifier. Its attenuation at mid-setting is balanced by a similar network between the output attenuator and the differential amplifier, as shown in figure 7.

The setting of the first of these networks is indicated on a dial calibrated in response to plus and minus 1dB, with markings at 0·05dB intervals. The second network is adjustable by uncalibrated coarse and fine Differential Balance controls to bring the oscilloscope deflection to zero at the reference frequency when the Response dial is set to zero.

Having made this adjustment, the relative response at any frequency is found by simply adjusting the Response control to bring the point on the display corresponding to the frequency of interest to the zero deflection level as shown in figure 8. The relative response is then read directly from the calibrated dial.

THE LIMIT GRATICULE

When making adjustments to amplifiers and other networks, it is usually more convenient to read from the display the extent to which the response characteristic remains flat within a predetermined limit, rather than measure the relative response at specific frequencies. Provision is therefore made for displaying a variable limit line or graticule together with the response characteristic.

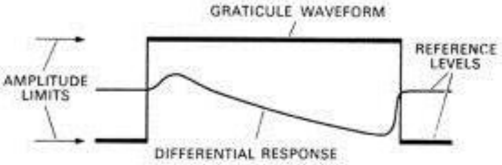


Fig.9(b) Differential display with superimposed graticule waveform.

This is achieved by feeding a calibrated fraction of the d.c from the input detector to a second differential amplifier as shown in figure 9, the difference in level between the terminals of the second amplifier being determined by the setting of the Response control. The input attenuation to the main amplifier is automatically fixed to correspond to zero on the Response dial when the instrument is switched to display the graticule. The outputs from the two amplifiers are applied alternately to the oscilloscope by means of an electronic switch – or chopper – at a switching rate equal to the field repetition frequency. Provision is made for locking the switching multivibrator to the blanking-pulse train when blanking is used.

Depending on the setting of the calibrated control the graticule line is displaced above or below the zero line to form a pedestal or trough. By adjusting a D.C Shift control the excursion of the displayed characteristic can be brought to lie symmetrically above and below the half-amplitude level of the graticule, so that parts of the characteristic outside the graticule limit are easily identified.

SOURCE AND LOAD IMPEDANCE

It is standard practice to use connecting cables of 75Ω characteristic impedance in television video systems; and it follows that 75Ω is the accepted input and output impedance for all transmission networks – except, of course, the head amplifier,

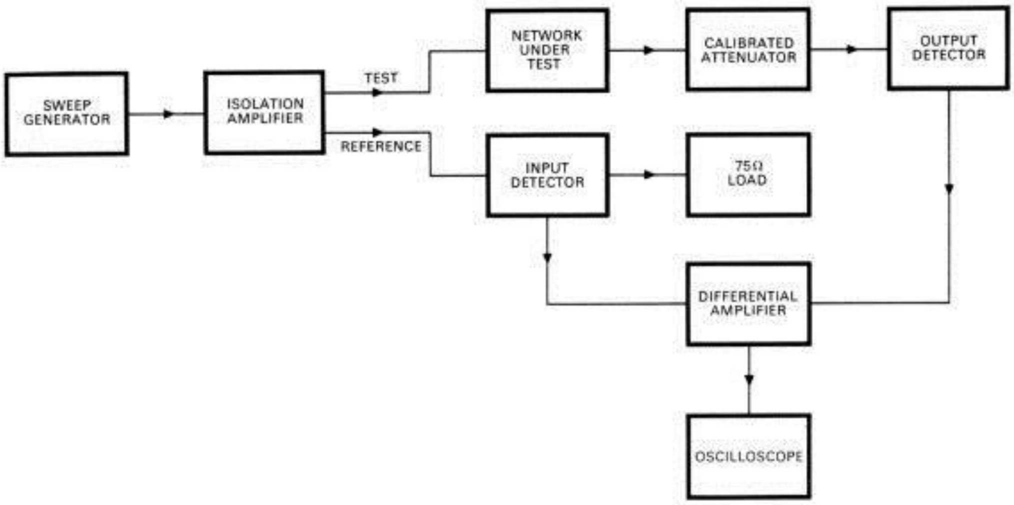


Fig.10 An amplifier having two identical 75Ω outputs isolated from each other facilitates differential measurement from an effective 75Ω source impedance.

which is normally tested with a special camera-tube-simulator at its input end.

So long as the network's input impedance is truly resistive, it makes little difference in measured response if the test signal is derived from a 75Ω or zero impedance source. But if, as is inevitably the case, the network's input impedance is complex it will behave as the lower arm of an unequalized divider when fed from a 75Ω source, with consequent effect on the overall response characteristic. With a zero impedance test source, on the other hand, the actual input voltage to the network is monitored, so that variations of input impedance with frequency do not effect the measured performance.

In the basic arrangement of figure 6 the input detector monitors the p.d developed across the network's input impedance so that any variations in this voltage are automatically compensated for in the measurement. Thus although the test signal may actually be derived from a 75Ω source, the measured characteristic is the one that would be obtained with a zero impedance signal source. The system thus measures the characteristic of the network alone, discounting the effect of complex source impedance.

This is a very useful attribute for the location of the cause of a falling or rising characteristic, but it is sometimes desirable to display the overall response characteristic, including the effect of the network's input impedance.

Provision is made, in the TF2907, for doing so by the inclusion of a buffer amplifier having two similar 75Ω outputs which are effectively isolated from each other. This circuit, the gain of which is actually 0·5 (i.e, 6dB loss), facilitates the connection of the arrangement shown in figure 10. Here the input detector monitors the voltage developed across a standard 75Ω load, while the network under test is driven from the same e.m.f and source impedance. The indicated response characteristic

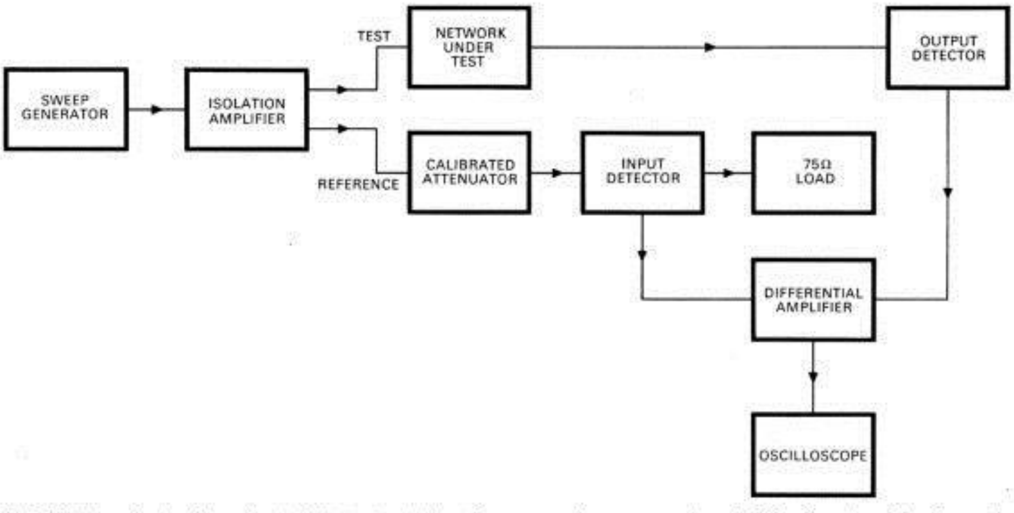


Fig.11 By transferring the calibrated attenuator to the reference arm the response characteristic of a network having a gain of less than unity can be displayed.

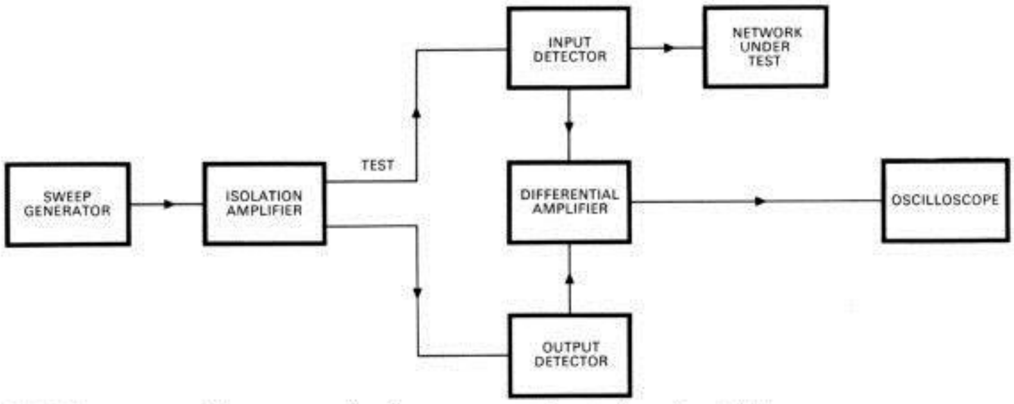


Fig.12 Rearrangement of detector connections for measurement of input voltage characteristic.

then includes the effect of variations in the network's input impedance with frequency.

The buffer amplifier is also useful for measurements on networks having less than unity gain. By connecting the standard attenuator between the reference output and the input attenuator, as shown in figure 11, the monitored reference voltage is reduced to be equal to that of the network's output at the reference frequency.

For diagnostic purposes, this dual facility for displaying the response characteristic of the network, with or without the characteristic of its input impedance, offers considerable advantage in locating the cause of excessive departures from flatness over the frequency band. For example, if the network shows a flat characteristic when measured with an effectively zero-impedance test source but a rising characteristic when measured with a 75Ω source, it is fairly obvious that the input impedance contains an inductive component.

By rearrangement of the detector connections as shown in figure 12 it is possible to display the variation of input voltage with frequency, thus showing whether or not the input impedance is truly resistive and of constant value over the swept frequency band. This test does not, in itself, show up any constant error in input resistance; but all the necessary circuits are present for doing so.

The measuring circuits are first standardized by fitting an accurate 75Ω terminating resistor to the input probe instead of the network to be tested. With this resistor connected and the Response dial set to zero, the coarse and fine Differential Balance controls are adjusted to produce zero input to the oscilloscope. When the amplifier is reconnected, any resistive error in its input impedance is shown up as a vertical displacement of the trace above or below the zero line.

The Response measurement control can, of course, be used to bring the trace back to the zero line and, for convenience, the Response dial also carries a calibration in ohms with 75Ω corresponding to the zero-error Response setting. In order to obtain a suitable scale-length and law, the constants of the measuring network are changed, by operation of a panel switch, to give an impedance measurement range of 65 to 85Ω.

With a complex impedance, giving a rising or falling displayed 'impedance characteristic', an indication of the degree of departure from 75Ω resistance at any frequency can be obtained by adjusting the measurement control to bring to the zero line the point on the display corresponding to that frequency.

A value in ohms can be read from a second scale on the measurement dial. This scale gives guidance to the resistive value of the impedance at low frequencies; but a sloping displayed characteristic would indicate a complex impedance, so that, at higher frequencies, the ohms calibration would no longer be valid.

The figure is, nevertheless, a useful one, particularly if the impedance at low frequencies is shown to be 75Ω. A rising impedance characteristic then usually indicates series inductance, while a falling characteristic is usually an indication of parallel capacitance.

The measurement is, of course, not confined to input impedance. It can also be used to show up errors in a network's output impedance, which is equally important in the achievement of a flat overall frequency response characteristic.

RETURN LOSS MEASUREMENT

When the impedance forms the termination to a coaxial cable, errors in its value or phase angle cause reflection effects which may be more serious, in terms of deformation of a television signal, than those due to variations in network response with frequency. In television engineering, the accuracy of the termination is normally assessed in terms of return loss; i.e. the ratio between the incident and reflected voltages expressed in decibels.

For measurement of return loss a special probe is supplied as an accessory to the TF2907. This Return Loss Probe is, however, actually a separate measuring unit, which is dependent on the TF2907 only for its power supply. It consists of a bridge circuit, as shown in figure 13, with a differential amplifier sensing the out-of-balance voltage. In the context of this article the excitation signal would normally be drawn from the Sweep Generator, which contains its own output

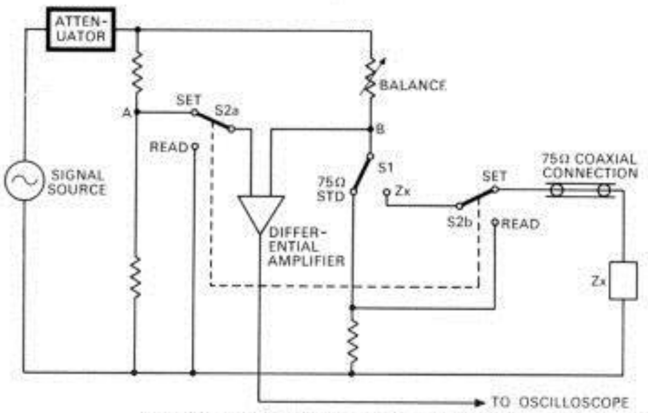


Fig.13 Simplified functional diagram of Return Loss Probe measuring circuit.

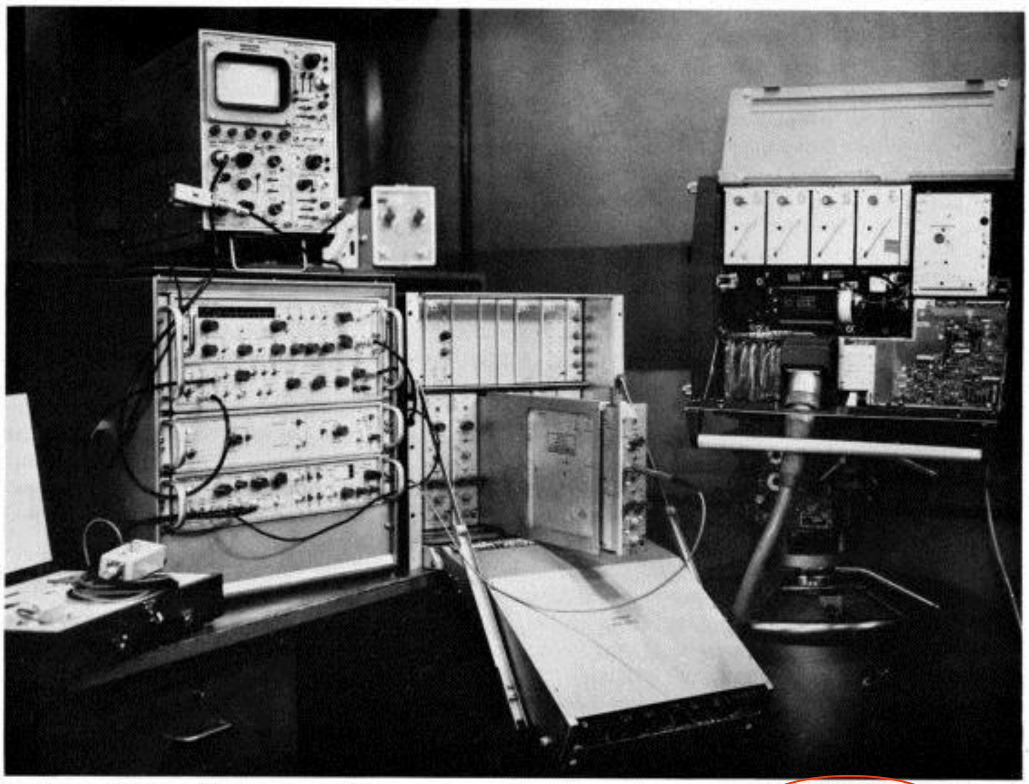
attenuator, but it may also be derived from a single frequency source or from a special television test-waveform generator.

With switches S1 and S2 in the positions shown the unit is simply a Wheatstone bridge. This is the initial setting up condition, in which the balance control is adjusted for zero deflection on the oscilloscope, so that the voltage at point A is equal to that developed across the built-in 75Ω standard resistance.

Switch S1 is then set to the 'Z$_x$' position, to connect the unknown impedance to the bridge instead of the 75Ω standard resistance. The action is best understood if it is assumed that impedance Z$_x$ terminates a length of coaxial transmission line having 75Ω characteristic impedance. Unless Z$_x$ is a pure resistance of 75Ω, a voltage (V$_r$) will be reflected back to the sending end of the line to add vectorally to the incident voltage (V$_i$). As the voltage at point A is equal in phase and amplitude to the incident voltage at point B, the voltage developed between the input terminals of the differential amplifier will be equal to V$_r$ regardless of the phase of V$_r$ relative to V$_i$.

The spot deflection on the oscilloscope screen is, therefore, directly proportional to the magnitude of the reflected voltage. As the return loss is equal to the ratio V$_i$/V$_r$ expressed in decibels, the return loss at any frequency can be found by displaying the incident voltage and then increasing the attenuation until it produces the same spot deflection as was obtained for V$_r$. To do so switch S2 is first set to the 'READ' position, thus reconnecting the bridge to the 75Ω standard resistance with the differential amplifier across the resistance. The attenuator is then adjusted to obtain the appropriate deflection at the position on the display corresponding to the frequency of measurement. The change in attenuator setting is then equal to the return loss at this frequency.

The length of the coaxial transmission line determines the phase of V$_r$ but does not affect its amplitude. As the measurement is independent of the phase of this voltage, the length of the transmission line may be reduced to zero without affecting the measurement; or, in other words, it may be omitted altogether.



Prototype model of the Television Sweep Analyser being used for response measurements on a Mark VIII Camera

Ed: Should be a MkVII camera