SCAN LOSS AND ITS ELIMINATION IN
CATV SWEPT FREQUENCY MEASUREMENTS

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This is a tutorial article on Scan Loss. Good construction and maintenance practices in conjunction with FCC and DOC specifications have emphasized the need for increased swept frequency measurements. Swept frequency measurements to determine: return loss, component isolation, flatness, spurious responses, probable causes of group delay as well as bench alignment and preinstallation checkout of passive or active system components.

Unfortunately, the possibility of amplitude error does exist especially in the case of severe amplitude changes (dB/MHz) through the mechanism of Scan Loss.

Please note the folowing photos of the swept response of a 0-300 MHz spectrum -- in which a Jerrold TLB-2 trap is inserted. Using a standard sweeper with variable sweep speed, an H-P 8471A detector, 3 feet of RG 58/u cable, and a storage oscilloscope calibrated 30 MHz per devision, two photos were made.

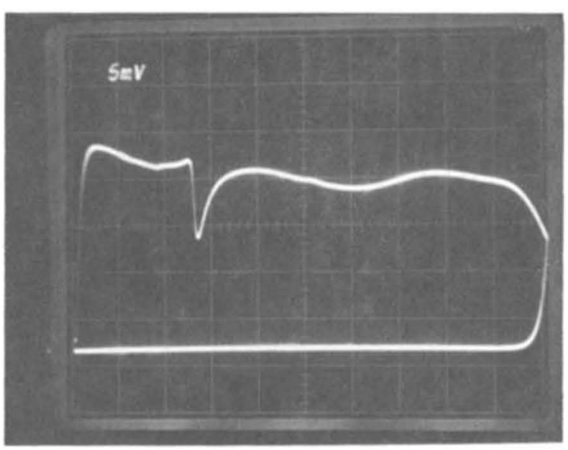


Photo A Sweep duration = 7 ms

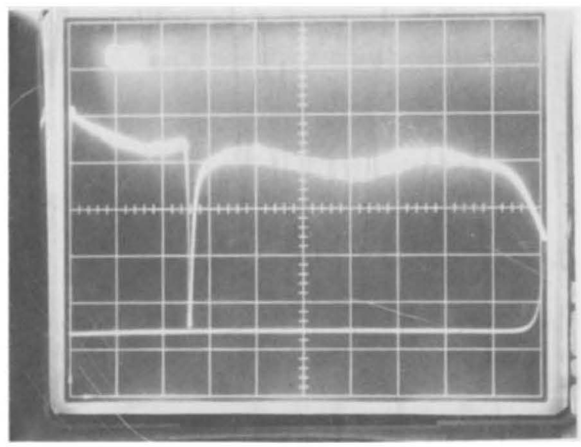


Photo B Sweep duration = 140 ms

When viewing the above photos, the question which comes to mind is: Which display is correct? Or, even possibly, Is either display correct ? Interestingly enough, the only variable in either case was sweep duration.

In plant construction and maintenance, you may frequently see severe amplitude changes as in the case of Photos C, D and E, taken with a log display CATV Sweep System known not to exhibit scan loss of a 12-channel plant

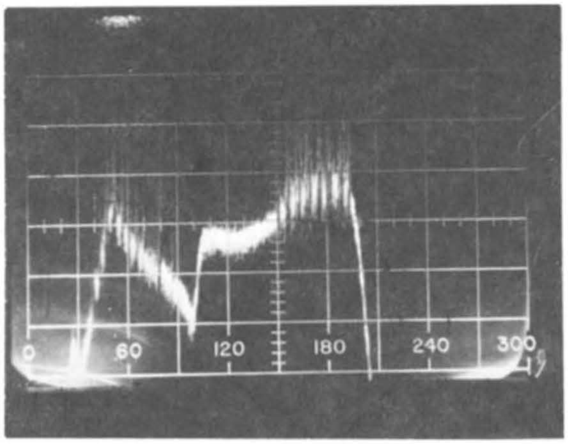


Photo C Vertical Sensitivity = 2 dB/cm

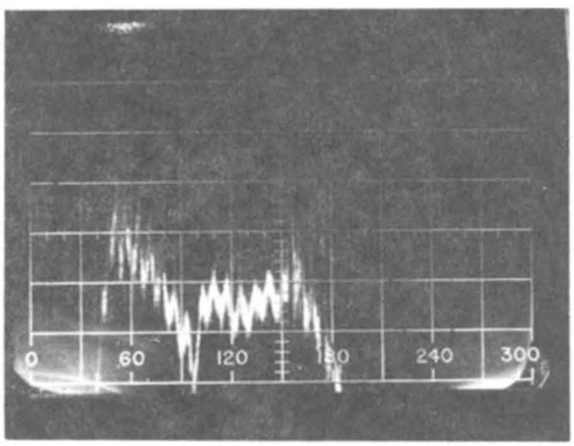


Photo D Vertical Sensitivity = 2 dB/cm

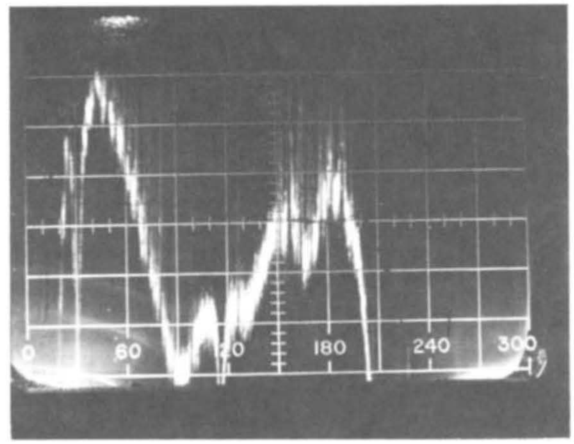


Photo E Vertical Sensitivity = 2 dB/cm

The problem is that if scan loss is present in our measurements (compare photos A and B), our construction and maintenance decisions are influenced by inaccurate information. In the case of Photos C, D and E, if scan loss were present, most of the problems could very well be masked or hidden.

The purpose of this paper is to make CATV Technicians aware of the scan loss phenomenon through definition and discussing its causes, recognition and elimination.

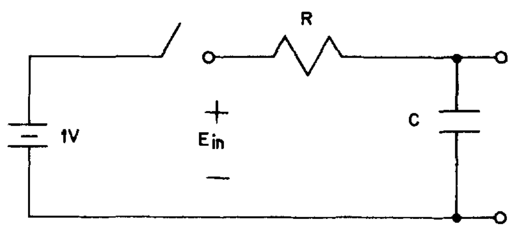
Definition (1)

Scan loss is the loss of amplitude resolution due to scan/sweep speed and is caused by the time constants associated with the detector, bandwidth of the receiver and response characteristic of the plant or device under test.

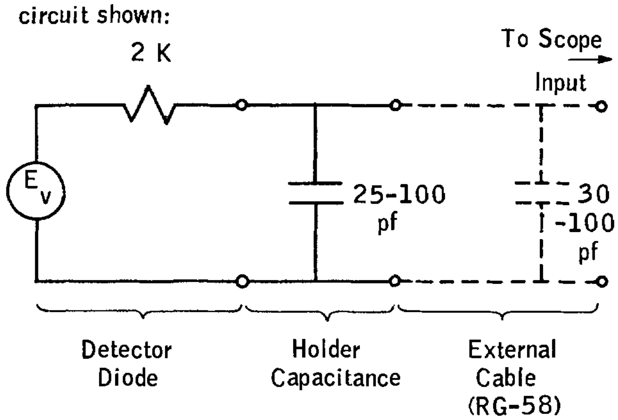
(1) Russell D. Anderson, "So, You're Finally Going To Buy Some New Test Gear?" TV Communications, February 1973 Volume 10, Number 2, pp 69-80.

Scan loss is aggravated or increased by faster sweep rates (MHz/sec) or reduced bandwidth. In either case, a large voltage change associated with a sharp change in system response may occur too rapidly for the filters (limiting bandwidth) to fully respond, giving an inaccurate replica of the voltage change.

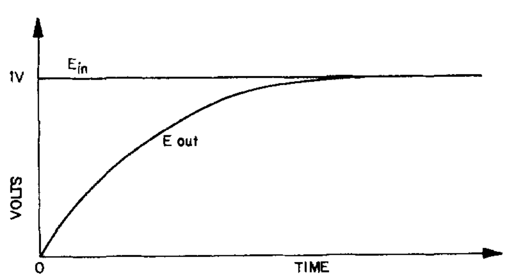
An example to consider would be the following RC filter:



Detector circuit — video frequency equivalent circuit shown:



At time 0, the switch is closed. The wave form is shown below:



The equation for E_{out} is

$$E_{out} = 1 - \epsilon^{\frac{-t}{RC}} \qquad (1)$$

The bandwidth of the RC filter can be shown to be

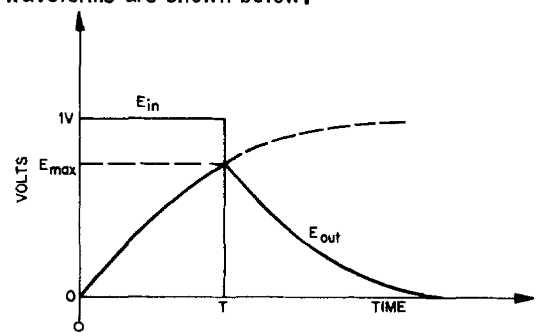
$$BW = \frac{1}{2\pi RC} \qquad (2)$$

The formula for E_{out} can be rewritten

$$E_{out} = 1 - \epsilon^{-t2\pi BW} \qquad (3)$$

In this case if we let t become very large, the output voltage will nearly equal the input.

Suppose, however, we have a pulse input. The waveforms are shown below.



The input pulse width is T. The maximum value E_{out} reaches during the pulse is

$$E_{max} = 1 - \epsilon^{-T2\pi BW} \qquad (4)$$

The loss in amplitude can be expressed in dB:

$$\text{Loss} = |20 \log E_{max}| \qquad (5)$$

or

$$\text{Loss} = |20 \log (1 - \epsilon^{-T2\pi BW})| \qquad (5a)$$

Now consider the case of a signal (whose frequency is being swept) driving a filter whose bandwidth is BW. If we know how long the signal is in the band BW, we can draw an analogy to the above example and determine how much loss there will be in the filter to a swept input signal.

Let the input signal frequency range be Δf Hz. Let the input sweep rate be SR sweeps per second.

The numbers of Hz swept in 1 second is $\dot{f}$

$$\dot{f} = \Delta f \times SR \frac{Hz}{second} \qquad (6)$$

To find the time that the signal is in the BW, let T_B be that time:

$$T_B = \frac{BW}{\dot{f}} = \frac{BW}{\Delta f SR} \text{ seconds} \qquad (7)$$

If (7) is substituted for T in 5(a):

$$\text{Loss} = \left| 20 \log \left(1 - \varepsilon^{\frac{-2\pi (BW)^2}{\Delta f SR}}\right) \right| dB \qquad (8)$$

This is called scan loss (loss due to scanning).

TABLE I

$$\text{Scan loss} = \left| 20 \text{ Log} \left(1 - \varepsilon^{\frac{-BW^2 2\pi}{\Delta f \times SR}}\right) \right| dB$$

Scan Loss as a Function of Sweep Speed

Case 1

Δf = 300 MHz
BW = 50 KC

SR	LOSS
10 S/S	.05 dB
20 S/S	.66 dB
50 S/S	3.75 dB
100 S/S	7.8 dB
200 S/S	12.8 dB

Scan Loss as a Function of Bandwidth

Case 2

Δf = 300 MHz
SR = 60 sweeps/sec.

BW	LOSS
10 KHz	29.3 dB
20 KHz	17.7
50 KHz	4.7
100 KHz	.27
200 KHz	.000007

Scan Loss as a Function of Sweepwidth

Case 3

BW = 50 KHz
SW = 60 S/S

Δf	LOSS
300 MHz	4.7 dB
100 MHz	.66
60 MHz	.11
30 MHz	.0014
6 MHz	0

NOTE: This table was calculated with the assumption of putting a pulse into an RC filter.

The generalizations that can be derived from this data apply qualitively to spectrum analyzers, and approximately quantitatively when BW is half the IF bandwidth.

In Table 1, some scan loss data are presented showing how it changes as BW, SR and Δf are varied.

The obvious conclusion to be drawn from the above is that any sweeping system will have some amount of scan loss. The real question is how much and how can it be effectively eliminated, which is answered in Table 1.

Consider the following example taken from Table 1, Case 3.

Example 1:

a) BW = 50 KHz
SR = 60 S/S
Δf = 300 MHz
Scan Loss = 4.7 dB

b) BW = 50 KHz
SR = 60 S/S
Δf = 30 MHz
Scan Loss = 0.0014 dB

In Example 1a) above, the scan loss is more than could generally be tolerated, however, scan loss 1b) is small enough to be practically unmeasurable.

To calculate scan loss for a given system the above equations are used; but two considerations must be made:

A. Is loss occurring because the cable response is active as the limiting filter? If so, this would principly be factor of sweep speed.

B. Once the cable plant is charged to any given value - will the receiver respond to the complete charge?

For example assume that a plant has a 1 MHz notch somewhere in a spectrum of 300 MHz and that sweep speeds of a) 25 ms and b) 2.5 ms are used.

Question, Will the cable charge to the full value? Using the equation in Table I above

$$\text{Scan Loss} = \left| 20 \log \left(1 - \ell^{\frac{BW^2 2\pi}{\Delta f \times SR}}\right) \right| \text{dB}$$

we find that scan loss is essentially zero in both cases.

This calculation assumes an infinate video bandwidth due to the matched impedance of the transmission system.

Since either sweep rate is adequate for seeing the 1 MHz notch, we must then determine what amount of scan loss will be contributed by the receiver bandwidth. To do this, we must use equation 5a above.

$$\text{Loss} = \left| 20 \log \left(1 - \ell^{-T 2\pi BW}\right) \right|$$

where T = time sweep is in the 1 MHz bandwidth and BW = video bandwidth of the receiver.

In example A above with a 25 ms sweep duration

$$T = 25 \text{ ms}/300 \text{ MHz or } 83.3\ \mu\text{sec}$$

and

$$BW = 50 \text{ KHz}$$

$$\text{Scan Loss} = 20 \log \left(1 - \ell^{-83.3 \times 10^{-6} \times 2\pi \times 50 \times 10^{3}}\right)$$

$$= 20 \log \left(1 - \ell^{-26.1}\right)$$

$$= \text{Approximately zero loss}$$

If the sweep speed is increased by a factor of 10, example B (2.5 ms sweep duration) above the equation is now

$$= 20 \log \left(1 - \ell^{-2.61}\right)$$

$$= .68 \text{ dB of loss}$$

Now assume that a crystal diode detector is used with a high impedance load (high impedance scope with 1 megohm input impedance) and that the total capacity of the scope detector and cable equal 100 pf. The resultant receiver BW is approximately 2 KHz.

$$\text{Scan Loss} = \left| 20 \log \left(1 - \ell^{-.104}\right) \right|$$

$$= 20.4 \text{ dB}$$

Therefore a significant amount of scan loss would be present. The obvious conclusion from this example is that a wider video bandwidth is needed for the receiver to see the 1 MHz notch. This can be accomplished by:

a) Detector biasing
b) Shorter cable between detector and scope
c) Lower capacity cable
d) Loading of the detector with external resistance but this reduces detector output voltage
e) Addition of a detector post amplifier without any cable length to lower output impedance without decreasing detector voltage
f) Slow sweep (approximately 10 sec.) with a high-resolution with X-Y plotter.

Recognizing Scan Loss

To maintain reasonable accuracy in flatness measurements or to insure that a true response is noted, one must be able to recognize scan loss.

The easiest way to accomplish this is to slow down the sweep speed when ever in doubt. If scan loss is present, the response shape will change (get worse). If this is the case, the sweep speed should be slowed until no further change can be detected.

A good way to accomplish this is to trace the sweep reference on the oscilloscope with a grease pencil before going to 1/2 sweep speed. The reference allows easy recognition of any response change.

Elimination of Scan Loss

Once Scan Loss is understood it is easily recognized and,therefore, can be essentially eliminated through one or may ways.

A. Selection of good quality sweep components

B. Use of very slow sweep rate

C. Slowing of sweep speed when in doubt.

Conclusion

Scan Loss, the loss of amplitude resolution due to time constant effect, is all too common in swept frequency measurements. This tutorial paper had discussed scan loss and its causes, recognition and elimination in hopes that it may be eliminated in CATV swept frequency measurements.