TIME SELECTIVE SWEPT RETURN LOSS
A NEW LOOK AT COAXIAL CABLE

JOHN L. HUFF
STAFF ENGINEER

TIMES MIRROR CABLE TELEVISION

ABSTRACT

Swept radio frequency return loss using a spectrum analyzer and tracking generator with time selection will provide a new dimension in the measurment of cable quality and integrity.

The return loss bridge has been a standard of measurment for the Cable Television industry. The bridge's short-comings are impedance balance, frequency bandwidth, connector adapters, and scan loss.

A spectrum analyzer, tracking generator, and a radio frequency counter with **Time Selective Swept Return Loss** will open up new avenues into coaxial cable testing and measurement. This technique could be particularly valuable in an HDTV environment. It is possible to analyze the effect of a single or a multiple of reflections from coaxial cable, connectors or other passive devices.

RETURN LOSS MEASUREMENTS

The detection of a swept radio frequency response from a bridge will indicate the quality of coaxial cable used in the Cable Television systems. The bridge makes impedance and reactance measurements possible. There are other devices that make the same impedance measurements.

Radio frequency bridges with port to port isolation of 60 Db from 10 kilohertz out to a gigahertz are available. Bridge effectiveness, however, is limited largely by the interface connector return loss.

Resolution of two reflections with a swept return loss display is possible. Resolution of three or more reflections is unsure.

The TDR with a stepped output measures the loop resistance and impedance characteristics of a coaxial cable. Broadband frequency response using a TDR is not easily determined. Making TDR measurements with Cable Television signals and power present on the cable system is not within the TDR's operational mode.

The **Time Selective Swept Return Loss** technique will change the way one thinks and uses the spectrum analyzer and tracking generator.

The block diagram of the test equipment and connections to the system's coaxial cable will appear bizarre. There will be differences in the setting of equipment's operating parameters. There is no set way the equipment should be connected to a test point. The connecting of cables should be as direct and short as possible, so that standing waves do not ocurr. standard procedures for blocking power to the test equipment should be observed. The procedures for connecting cables will be dictated by differences in equipment.

THEORY

The reciprocal of frequency is time. With a known propagation velocity and a measured time the length of a coaxial cable may be determined. There are two discrete time references when using the **Time Selective Swept Return Loss** technique. The first reference is the time it takes the spectrum analyzer and tracking generator to scan a band of frequencies. The second reference is the time it takes a signal to travel the length of coaxial cable. Both times are used to calculate the frequency (delay) between the spectrum analyzer and tracking generator.

DELAY AND APERTURE DEFINED

The "tracking" adjustment is used to track the spectrum analyzer with the tracking generator. The tracking adjustment is also used to adjust the offset frequency. The offset frequency determines the time or delay, between the tracking generator and the spectrum analyzer, and determines the point of the segment of cable to be analyzed. The offset delay is adjustable from zero to over 3 microseconds or 2400 feet.

By adjusting the IF bandwidth scan time and frequency span, one can determine the aperture of the spectrum analyzer. By adjusting the aperture, one selects the time or length of coaxial cable to be analyzed. The **aperture** is variable in time from 5 to 1500 nanoseconds or 5 to 2500 feet in coaxial cable.

EQUIPMENT OPERATING PARAMETERS

```
|-----------coaxial cable---------------|
<-DISTANCE--------------2500 feet------>|
|-OFFSET------><------to--300 KHz------>|
|-DELAY-------><------to-3 microseconds>|
|-adjustable-><-------------------------|
|             |---adjustable-------|
|---APERTURE-><5 to 1500-nanoseconds><--|
0-----------coaxial cable-------------->|
|<--DISTANCE -------------2500 FEET---->|
```

AN RF SPAN OF 1000 MHz AND
THE RATES OF

SCAN AT	1.	.5	.2	.1	milliseconds
IF KHz					APERATURE IS
of 3	33	16	10	5	nanoseconds
of 10	100	50	20	10	nanoseconds
of 30	300	150	75	30	nanoseconds

THE OFFSET OF 100 KHz PROVIDES
500 nanoseconds OF DELAY

AN RF SPAN OF 200 MHz AND
THE RATE OF

SCAN AT	1.	.5	.2	.1	milliseconds
IF KHz					APERATURE IS
OF 3	165	80	50	25	nanoseconds
OF 10	500	250	100	50	nanoseconds
OF 30	1500	750	375	150	nanoseconds

THE OFFSET OF 100 KHz PROVIDES
2500 nanoseconds OF DELAY

The **aperture** table will not change with the types of equipment used. Calibration correction factors will change.

Standard CATV test equipment is not calibrated to operate **Time Selective Swept Return Loss** accurately.

The operating limit of the time scan depends on the spectrum analyzer local swept oscillator. The limit is on the local sweep oscillator's ability to track a linear time and sweep frequency.

With some tracking generator, spectrum analyzer combinations, tracking may not adjust with enough offset range. A second adjustable oscillator may be used to give the needed offset. The adjustable oscillator output is read directly with a frequency counter.

Scan and frequency amplitude response loss do not apply the same with **Time Selective Swept Return Loss.** The high sweep speed and narrow IF bandwidth will reduce the effect of other signals that are on the system and enhance the desired signals.

OPERATIONAL NOTES

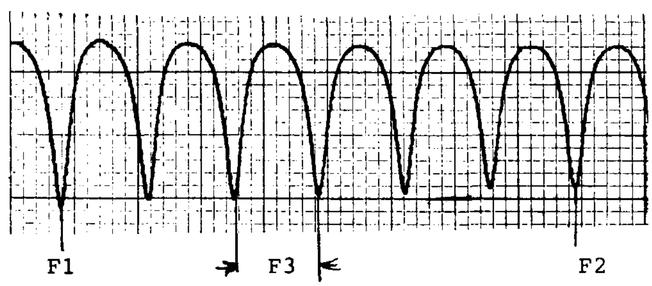
Five operating conditions exist with **Time Selective Swept Return Loss** which would not be normal for conventional swept radio frequency measurements:

1. A narrow IF bandwidth
2. A high rate of swept radio frequency
3. A wide band of frequencies swept
4. At least 50 nanosecond of propagation time delay
5. A very linear frequency and time sweep of the first local oscillator

It is not usual to sweep test with a narrow IF bandwidth. The IF bandwidth affect markers or other signal responses occupying critical swept frequencies.

CROSS CHECK

Standing waves of sweep frequency amplitude response is used to cross-check total length of a coaxial cable and to calculate delay time corretion.



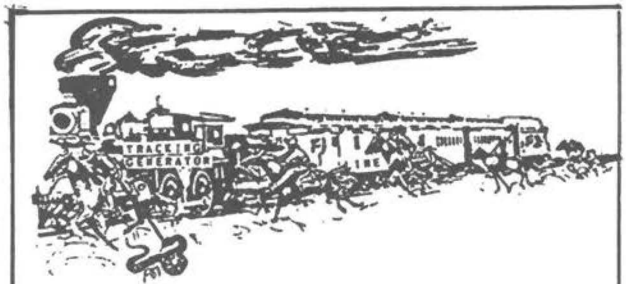
(1/((F2-F1)/6)X.5=time in microseconds
microseconds X 984=free space distance
free space distance X 88%= coaxial feet

```
 F2 = 79.581 MHz
-F1 = 63.947 MHz
    ---------
      15.634 / 6 = 2.6056 MHz = F3
      1 / 2.6056 = .38378
.38378 X .5 = .19187 microseconds
.19187 X 984 = 188 feet free space
188 X .88% = 166 feet coaxial cable
```

OPERATION

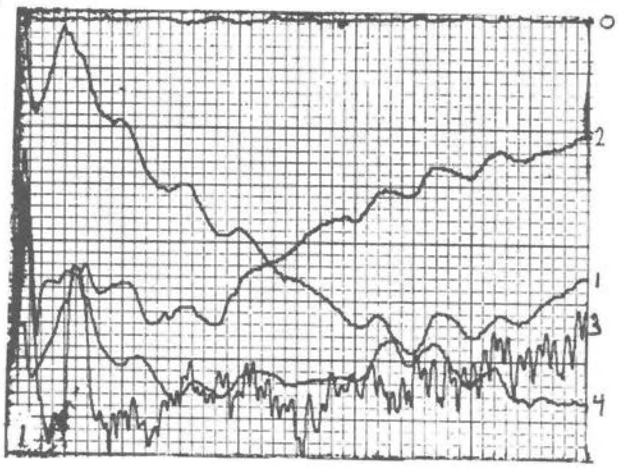
Connect a coaxial T to the tracking generator output. Connect one leg of the T to the spectrum analyzer input. The third leg is connected to a length of coaxial cable not less that 200 feet. The other end of the cable should not be terminated. Using the standing waves interference pattern, the cable length can be measured.

Compare **Time Selective Swept Return Loss** technique to and old western movie. Picture a fast moving train, the robbers are riding their horses alongside the train and can board any car.



One horseman takes out the "F81" rattlesnake, the other horsemen pace the train to check couplings and cargo and to prepare for boarding.

"THE SPECTRUM TSSRL ANALYZER GANG"

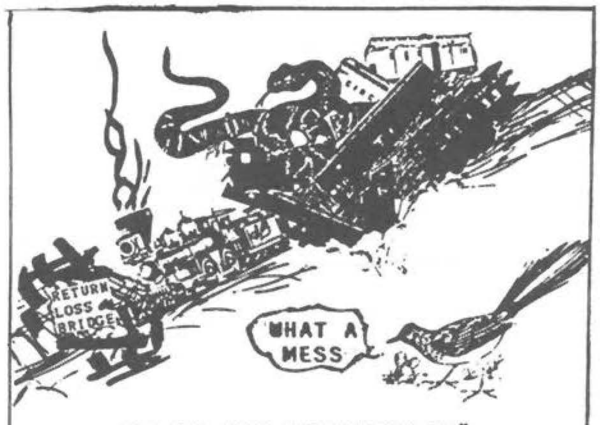


T.S.S.R.L. OF SAMPLE COAXIAL CABLE

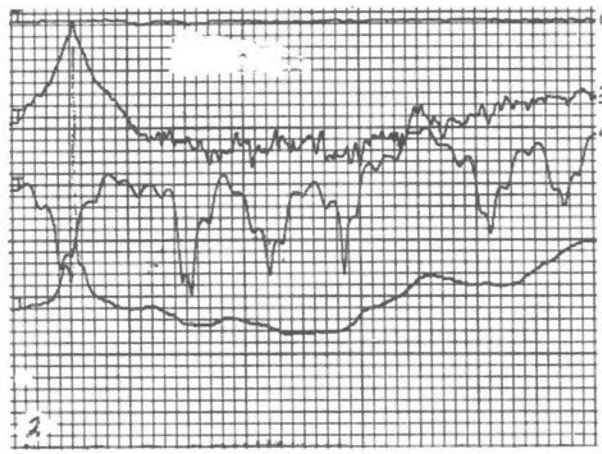
Zero reference span from -100 to +900 MHz. Zero reference offset frequency 499.7245MHz.
1. Bridge terminated with a standard termination 60 DB return loss at 600 MHz.
2. Cable connected through an F81 has a 34 return loss at 500 MHz.
3. Return loss of inter connecting cable is greater that 60 dB through 700 MHz. The offset frequency is 12 KHz.
4. Return loss from the 1.8 microsecond length of 500 coaxial cable is 54 dB.
The offset frequency is 340 KHz.

The TDR traces to the right are a sample of .5 inch coaxial cable 1.8 microseconds long. The botton trace expands five time the first .5 micro-seconds of the top trace. The T.S.S.R.L. plots on the next page correspond to the discontinuities traced by the TDR. Five small vertical divisions are one ohm impedance. The T marks a coaxial cable connector, the causes of the other changes in impedance are not known.

The present bridge method for return loss measurements is like putting railroad ties on the track to stop the train. The result is a pile of train cars on the railroad tracks.

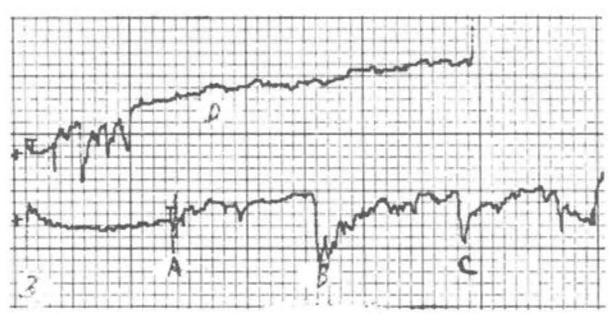


"YE OLD LOST BRIDGE RETURNS"

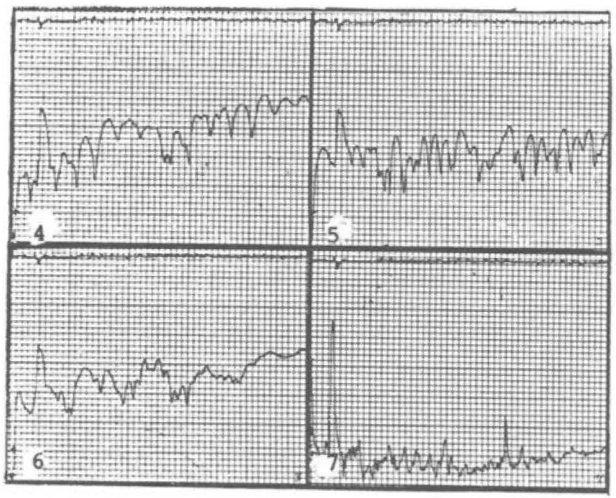


A series of plots made with a bridge with the standard method.

1. A zero dB reference trace with the bridge test port not terminated.
2. A quality termination on the bridge with 52 dB return loss at 500 MHz.
3 The return loss of the sample cable without the extreme end being terminated, a return loss of 21 dB at 300 MHz.
4. And expanded section of 10 MHZ span centered at 400 MHz showing the multiple responses from multiple reflections.



The TDR sample of coaxial cable was swept from a minus 100 MHz to a plus 900 MHz. Below are plots with various delays return losses as a continuation of plot 1. Each plot displays 80 dB vertical.



T.S.S.R.L WITH SELECTIVE DELAYS

PLOT	POINT	OFFSET	DELAY
#4	A	45.7 KHZ	118.0 ns
#5	B	68.0 KHz	228.5 ns
#6	C	84.9 KHz	340.0 ns
#7	D	124.4 KHz	625.0 ns

T.S.S.R.L. WITH SELECTIVE DELAYS
A a 500 splice connector.
B and C unknown underground faults.
D a repeated impedance changes 9;96 inches apart, a manufacture's characteristic.
The return loss is at 550 MHz as a spike.

Set the spectrum analyzer scan width to 500 megahertz. Set the sweep speed to 5 or 10 millisecond. Set the IF bandwidth from 3 to 30 KHz. Set the vertical calibration to log 10.

Adjust the tracking generator frequency offset to about 100 KHz. Set the vertical dynamic range to 70 or 80 Db. The vertical response above the noise floor is the return loss. Continue the offset through 300 KHz. The open end of the length of coaxial cable will be a swept R.F. amplitude response. The response will be twice the through loss of the coaxial cable. The coaxial T coupling provides an accurate output level reference.

OPTIONS

To use **Time Selective Swept Return Loss**, a frequency counter and a second, 2nd or 3rd local oscillator is not needed. To improve accuracy, reduce time and equipment operational confusion, a second offset oscillator is desirable. A frequency counter could be used with the offset oscillator in the tracking generator if there was a sample output of that oscillator.

There is an alternate method to offset frequency measurement. Stop the sweep of the spectrum analyzer in mid sweep, count the frequency of the tracking generator. A second frequency measurement is made after a tracking offset change has been made. The midsweep output frequency difference is the offset. The frequency offset of the tracking generator will determine the spectrum analyzer time delay.

TECHNIQUE

One has a 50/50 chance that the first offset frequency adjustment will be in the right direction. Only one direction has a response from on frequency tracking.

The offset frequency determines the delay time of the spectrum analyzer. A delay is an increase in frequency of a **tracking generator** offset oscillator. There is a decrease in frequency of the offset oscillator in a **spectrum analyzer.**

The bridge or directional coupler will extend the dynamic range of the spectrum analyzer. The bridge or directional coupler provides the isolation for observation of the reflections close to their test port. Isolation created by the directional coupler or the bridge must be included in return loss calculations.

Characteristics of a bridge are displayed as the balance is adjusted. The bridge balance adjustments are not effective as the spectrum analyzer delay time moves away from the response of the bridge.

Time Selective Swept Return Loss examines any section of a coaxial cable. All the passive equipment that is placed on the coaxial cable to the next active device can be examined for return loss.

The advantages of **Time Selective Swept Return Loss** will become apparent when you see the return loss of a coaxial cable being 70 Db or better. A connector at 500 feet may have a return loss of 40 Db at 50 megahertz and 20 DB at 400 megahertz.

Coaxial cable loss must be subtracted from the return loss measured. All intervening coaxial cable loss and the resulting return loss from that section of coaxial cable is added. The swept radio frequency through loss is in one direction of a length of the coaxial cable. The through loss is half of the return loss of the signal reflected from a coaxial cable that is not terminated.

The relative location of two close spaced reflections or the interference pattern of multiple reflection can be resolved with ease. The coaxial characteristics will be displayed in a variety of new responses. Other electronic passive devices on the cable will also reveal their particular characteristic influence.

Try **Time Selective Swept Return Loss** on TV receiving antennas and coaxial cable. The true return loss of the coaxial cable or the TV receiving antenna can be determined.

SUMMARY

Time Selective Swept Return Loss is not a **solve all** or a **cure all.** The technique will solve many problems dealing with television signal loss and distortion on a coaxial cable.

It is not possible here, to cover all the aspects, uses, and possibilities of **Time Selective Swept Return Loss.**

A new user may accept the technique as being a more normal function of the spectrum analyzer and tracking generator.

Test equipment calibrated and control panel marked to perform the required functions of this technique, operations would be easier.