WHAT IS RETURN LOSS, AND WHY SHOULD I MEASURE IT?

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Once upon a time, "Return Loss" was a somewhat arcane term and used mainly with regard to high frequency transmission lines and the impedance transformations that could be the result of these reflected signals. Now however, with the advent of high speed Data transmission such as the various digital television standards, Return Loss considerations are experiencing renewed interest. This data transmission problem comes about because this "return loss" signal may mix in with subsequent data signals, compromising the quality of the received signal and possibly creating data errors because of the mixing of signals.

By definition, "Return Loss" refers to that portion of a signal that cannot be absorbed by the end of line termination, or cannot cross an impedance change at some point in the transmission system. This component of the signal is reflected from the impedance discontinuity and travels back up the line from that point, since it cannot be absorbed by the termination, or traverse the impedance irregularity. That causes two signals to appear on the coaxial cable, one going in one direction and the other in the reverse direction. These two signals cancel and add along the line at various points. When these cancellations occur at a receiving terminal end of the cable, data may be lost forever. This is what causes concern with regard to RETURN LOSS on data transmission systems, especially digital video transmission systems.

"Return Loss" is generated by any change in impedance of a cable (due to changes in physical dimensions, or type of insulation), or for that matter, even coaxial cable connectors used in the cable system, not to mention the actual termination provided by the terminal equipment. In a broadcast television network there are hundreds, if not thousands of sources of these reflections. Most are very small irregularities, but can add up over many such impedance changes. These irregularities can cause the amplitude and phase (zero crossings) to jitter, and ultimately cause enough error to result in data failure. In addition to the cumulative effect of large numbers of small irregularities, a small number of large discontinuities can also cause this effect. An example of this condition occurs when there is a nearby lightning strike strong enough to burn out or change the value of terminating resistors. This can decrease the "Return Loss" enough in that cable section to induce data errors into the system.

In order for a reflected signal to interfere with the original signal, it must first reflect off of the receiving terminal impedance toward the transmitting terminal, then reflect back again from that sending terminal back down the cable and arrive (somewhat delayed) at the receiving terminal. This process creates a long double trip that requires two sets of reflections and the signal loss of two transitions down the cable. This creates some loss in the reflecting signal, but the (direct) signal also suffers some cable loss, so the reflected signal interferes with a weakened direct signal. The greatest possibility for interference occurs when the cable is short and the reflections at each end of the cable are large.

The formula for calculating the amount of Return Loss created by any discontinuity in a coaxial cable is as follows:

$$\text{Return Loss} = 20 \log_{10} \frac{Z_t - Z_o}{Z_t + Z_o}$$

where Zt = Terminating Impedance

and Zo = Cable Characteristic Impedance = $\sqrt{\frac{L}{C}}$

Note that since the characteristic impedance of a coaxial cable is equal to the square root of the inductance of the cable divided by the capacity of that cable, then as long as the dimensions and construction of the cable remain the same along its length, the characteristic impedance will remain constant throughout the entire cable. Coaxial cable must be manufactured very carefully. Any repetitive dimensional changes induced by the manufacturing process, such as cyclic variable compression or tension on the shield wires can cause reflection at specific frequencies, and thus sharp absorption "notches" in the frequency response of that particular cable. Any change in the cross section of the cable, such as where connectors are placed will inevitably introduce some impedance discontinuity and thus Return Loss. A large number of patch panels, while beneficial from an operational point of view, will introduce some "Return Loss" into the transmission system.

Any change of impedance along a cable creates and opportunity for a reflected signal that can interfere with the primary intended signal. Cable connectors are designed to reduce impedance irregularities as much as possible when correctly installed. Poorly installed coaxial connectors can aggravate the impedance irregularities if the connector has improperly trimmed center or shield wires, insulation, or incorrect compression and soldering of components of the connector. It pays to be very careful when applying a connector to a cable. Be sure to follow the installation instructions of the connector manufacturer exactly, particularly relating to trimming of insulation and the other trimming dimensions. It is a good practice use only continuous lengths of coaxial cable on any given cable run, rather than to splice a cable in the middle of a run for these reasons.

The following table shows the relationship between termination resistance and the return loss value in a 75 Ohm coaxial cable:

TERMINATION RETURN-LOSS TABLE

TERMINATION ACCURACY	75 OHM TERMINATION LOWER LIMIT	UPPER LIMIT	RETURN LOSS	SIGNAL REFLECTION
+/- 0.1 %	74.925	75.075	66.0 dB	0.05 %
+/- 1.0 %	74.26	75.75	46.1 dB	0.5 %
+/- 2.0 %	73.53	76.50	40.1 dB	1.0 %
+/- 5.0 %	71.43	78.75	32.3 dB	2.4 %
+/- 10.0 %	68.18	82.50	26.4 dB	4.8 %
+/- 20.0 %	62.50	90.00	20.8 dB	9.1 %
+/- 30.0 %	57.69	97.50	17.7 dB	13.0 %
+/- 40.0 %	53.57	105.00	15.6 dB	16.7 %
+/- 50.0 %	50.00	112.50	14.0 dB	20.0 %

Note that it is quite possible to find a 50 Ohm termination plugged into a 75 Ohm cable system, since 50 Ohm impedance is a coaxial standard impedance, and a much greater used impedance at these frequencies. The accidental use of a 50 Ohm termination would incur a reflection of 20 % in amplitude, which could easily cause data transmission errors if the transmitting termination was not excellent. While an exact 75.0 Ohm transmitting termination would absorb all of the reflected energy, a transmitting termination that was not accurate would cause some of that energy to return and mix with the original signal and possibly cause data errors. What this condition suggests is that not only should the receiving termination be measured and determined to be within desired tolerances, but the transmitting termination must also be measured. The transmitting termination and receiving termination must be measured with the power turned "on" in all cases, otherwise the equipment will not reflect the actual (active) operating terminations.

Another problem with connectors that are manufactured for 50 Ohm coaxial cable, is that the actual center pin of the 50 Ohm BNC coaxial connector is a slightly larger diameter than the 75 Ohm BNC model and will not "mate" with the 75 Ohm BNC connector correctly. The 75 Ohm and 50 Ohm BNC connectors look very much alike and will fit together, but doing so will damage the 75 Ohm female connector permanently. When connected together, the 75 Ohm female connectors center socket will be over stressed and bent outward permanently destroying the connector. If a 50 Ohm female connector is used it may only intermittently connect to the male 75 Ohm connector. These are serious considerations to be taken into account when the two impedance standard BNC connectors are both found in one location. Be especially careful when purchasing BNC connectors because the 50 Ohm type of connector is far more prevalent in the market place.

RETURN LOSS is a matter of serious concern on any transmission system for a digital television signal, and knowing the magnitude of the Return Loss at the sending end termination, receiving end termination, and each and every connecting cable is of primary concern. That is WHY it is important to measure the RETURN LOSS of all terminations in your digital video transmission systems. You can use the SDI MASTER to measure your terminations and much more. Call FM SYSTEMS, INC. at: 1-800-235-6960 and order one today.