HOW TO KNOW WHEN YOU'VE BEEN ZAPPED, OR PRACTICAL TECHNIQUES FOR SELECTING A RELIABLE ATTENUATOR FOR USE IN HIGH VOLTAGE PULSE MEASUREMENTS

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ABSTRACT

This paper outlines practical techniques to minimize equipment breakdown and measurement errors that result from attenuator failure during measurement of high voltage pulses. Some common failure modes in attenuators will be identified. A simple method for logging the resistance history of an attenuator, and detecting attenuator failure is included. Attention will be given to the problems associated with selecting the proper attenuator for pulse power measurements. This includes a simple method for testing an attenuator to determine its high voltage capabilities.

INTRODUCTION

The measurement of high voltage pulses with low voltage ultra wide bandwidth oscilloscopes poses a serious problem. Since these oscilloscopes are not designed to directly measure high voltage, attenuators must be used to reduce the energy to safely measurable levels. A problem exists because most wide bandwidth microwave attenuators are not designed for high voltage and their use may result in inaccurate data and expensive damage to the measurement equipment. The solution comes through an understanding of the problem and the selection of an appropriate attenuator.

COMMON FAILURE MODES FOR ATTENUATORS

The maximum voltage and pulse width that an attenuator will pass is limited by a number of factors. Most microwave attenuators have very short resistive elements to obtain the widest bandwidth. This limits their high voltage capabilities probably more than any other factor. A plasma arc completely across these resistive elements results in decreased attenuation and possible permanent damage to the resistive element, not to mention possible damage to other equipment in the system. Plasma arcs from the inner conductors or the resistive elements to ground are also a serious problem. These can also cause major distortions to the waveform and permanent damage to the resistive elements. Another type of failure occurs commonly with film resistors. Voids or high resistive areas commonly exist in the film. A plasma arc often occurs across these points resulting in further film damage.

Another limit is imposed by the connectors commonly used on attenuators. Practical limits, assuming that the connector internal and rear interface is designed to withstand an equal or greater DC voltage than the connector interface, are as follows: 4kV for the "N" connector, 6kV for the GR 874 connector, and 15kV for the "HN" connector. These connectors can be used at higher voltages at sub-microsecond pulse widths.

Cable connectors also have these same limitations. Their voltage capabilities are often limited by the cable-to-connector transition, which can cause breakdown below the above mentioned ratings.

RESISTANCE LOGGING

One should not assume that an attenuator is good simply because it appeared to function properly the last time it was used. Before any attenuator is inserted into a measurement system it is good practice to measure the device, to insure that the DC resistance is within the desired tolerance. A method that works well is to maintain a separate resistance log for each attenuator used for high voltage pulse measurements. In this log keep track of the attenuator's resistance history by recording the resistances immediately before installing the attenuator into the system and after high voltage use. This provides a means for the recognition of failure, or a trend leading to imminent failure. An example of a log form is shown below.

ATTENUATOR DC RESISTANCE LOG

MFG:___________________________________

MODEL #:_________ SERIAL #:_____________

DATE	RES END A	RES END B	ROOM TEMP	COMMENTS
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To actually test a device, first measure your terminators, selecting one that is as close to your system impedance as practical. Record the measured resistance of the selected terminator on the log form. Terminate the attenuator output with this load, then measure and record the resistance of the input port. If it is a 2 way device, do this measurement again, reversing the input and output port. The use of a high precision digital bench meter with a 4 wire probe arrangement is recommended. However, with this level of precision, thermoelectric effects and temperature coefficient effects can be seen. It is important to allow enough time for the meter reading to stabilize, before recording the value. Increases greater than ¼% (.02 ohms for a 50 ohm system) should be regarded with caution. Any attenuator that shows an increase greater than 2% should not be used for a high voltage application.

SELECTION OF A PROPER ATTENUATOR

The first step in selecting an attenuator is defining your particular requirements. The most important parameters are maximum voltage input, maximum pulse length, and maximum average power[1]. Other parameters, not covered in this article, that might be considered are voltage coefficient, temperature coefficient, and reflection coefficient. Once the parameters are defined, try to find an attenuator whose ratings meet your requirements. If sufficient ratings are not in the manufacturers catalog, contact the manufacturer directly. If high voltage specifications are unavailable, it is good assumption that the manufacturer does not high voltage test the attenuator. This leaves it up to the user to test the device to determine if it will meet his requirements.

ATTENUATOR HIGH VOLTAGE BREAKDOWN TESTING

In the absence of adequate manufacturer specifications, there is a procedure that can effectively be used to test an attenuator. First the attenuator is measured and resistances recorded on a resistance log as outlined above. It is then pulsed, for a minimum of 1000 pulses, at a voltage and pulse width similar to how the unit will be used. Care should be taken not to exceed the average power dissipation for the unit. The output of the device is monitored during the test on a simple real time 100 MHz oscilloscope[2] for any distortions of the output which is an indication that the device is failing.

After pulsing, the attenuator is measured again and recorded on the resistance log. If the device passes this test, it is less likely that this particular attenuator will breakdown during actual use. However, unless the manufacturer provides acceptable high voltage ratings, one can not assume that any other attenuators “identical” to the tested attenuators will not fail under high voltage.

CONCLUSIONS

The procedures discussed for the selection and testing of attenuators will help prevent damage to measurement equipment. Any attenuator that is going to be used in a high voltage application should be high voltage tested before actual use.

1. Average power can be related to Pulse voltage, pulse width, and rep rate as follows:
Average Power = peak power x pulse length x rep rate (pps)

2. Oscilloscope damage can result from a defective or inadequate attenuator, so consider using an oscilloscope that is inexpensive to repair or replace.