

# AN INEXPENSIVE HIGH VOLTAGE PROBE\*

by

R. Dollinger and D.L. Smith  
Plasma Laboratories  
Department of Electrical Engineering  
P.O. Box 4439  
Texas Tech University  
Lubbock, Texas 79409

## ABSTRACT

A simple, easily constructed, high voltage probe ( $\approx 300$  kV) with a good frequency response ( $\approx 100$  MHz) and high input impedance ( $\approx 10$  k $\Omega$ ) is desirable in many applications. Such a probe, constructed of two concentric cylinders of "Velostat"<sup>1</sup> is reported.

## Introduction

There are several well-known voltage divider techniques employed as high voltage probes. A capacitive and an inductive divider are shown in Fig. 1. Both suffer from high frequency ringing noise caused by the ever present stray reactances. They also place a reactive loading on the measured circuit that is often undesirable because the loading is frequency dependent. The more familiar resistive divider, as shown in Fig. 2, has a limited frequency response because the signal may be shunted directly to ground by the stray capacitances and especially the variable stray capacitances. Decreasing the total chain resistance tends to improve the high frequency response; however, to prevent loading down the input circuit the total resistance should be as large as possible. Typical resistive dividers have a total resistance of  $\approx 100$  k $\Omega$  and a frequency response of  $\approx 500$  kHz.

The high frequency response can be improved by placing the resistive divider chain in a known electric field to decrease the effect of the variable stray capacitances. Two methods for doing this are shown in Fig. 3. A cylindrical metal housing for the chain, which is well sealed for shielding purposes, is not convenient to construct. Placing the chain between two large metal electrodes has the disadvantage that the electrodes must have a radius of curvature much larger than their separation distance. Thus, for a large voltage holdoff, the electrode size makes them necessarily expensive to construct and not very portable.

A method of providing a uniform electric field and graded stray capacitances around the resistive divider chain is by enclosing the high voltage chain inside a second resistive divider chain in a concentric cylindrical configuration. See Fig. 4a.<sup>2</sup> This allows the use of

---

\*This work was supported by the National Science Foundation and the Air Force Office of Scientific Research.

## Report Documentation Page

*Form Approved*  
*OMB No. 0704-0188*

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE <b>NOV 1976</b>	2. REPORT TYPE <b>N/A</b>	3. DATES COVERED <b>-</b>	
4. TITLE AND SUBTITLE <b>An Inexpensive High Voltage Probe</b>		5a. CONTRACT NUMBER	
		5b. GRANT NUMBER	
		5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)		5d. PROJECT NUMBER	
		5e. TASK NUMBER	
		5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) <b>Plasma laboratories Department of Electrical Engineering P. O. Box 4439 Texas Tech University Lubbock, Texas 79409</b>		8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)	
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT <b>Approved for public release, distribution unlimited</b>			
13. SUPPLEMENTARY NOTES <b>See also ADM002371. 2013 IEEE Pulsed Power Conference, Digest of Technical Papers 1976-2013, and Abstracts of the 2013 IEEE International Conference on Plasma Science. Held in San Francisco, CA on 16-21 June 2013. U.S. Government or Federal Purpose Rights License</b>			
14. ABSTRACT <b>A simple, easily constructed, high voltage probe (~ 300 kV) with a good frequency response (~ 100 MHz) and high input impedance ~ 10 kn) is desirable in man.v applications. Such a probe, constructed of two concentric cylinders of "Velostat"l is reported.</b>			
15. SUBJECT TERMS			
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT
a. REPORT <b>unclassified</b>	b. ABSTRACT <b>unclassified</b>	c. THIS PAGE <b>unclassified</b>	<b>SAR</b>
			18. NUMBER OF PAGES <b>6</b>
			19a. NAME OF RESPONSIBLE PERSON

electrodes similar to but much smaller than those of Fig. 3b. The probe in Fig. 4a has an input impedance  $\approx 30 \text{ k}\Omega$ . It has a frequency response of  $\approx 200 \text{ MHz}$  and can withstand voltage potentials of  $\approx 100 \text{ kV}$  in air or  $\approx 300 \text{ kV}$  if immersed in oil. Although the probe works very well, it has the disadvantages that the design requires special order resistors (5 ea:  $10 \text{ k}\Omega$ , 11 J) with a long delivery time and that its initial construction is not simple, particularly because it is somewhat difficult to separate the oil and electrolyte and seal their reservoirs without trapping or forming bubbles. This compact arrangement is a big improvement over those of Fig. 3, but the probe is still not light, especially when immersed in oil. Finally, one is hesitant to measure the unknown voltage of a high energy source for fear of exceeding the probe's high voltage or power rating and damaging the unit.

We, therefore, have built and tested a probe of the type shown in Fig. 4c, which has the distinct features of being simple (3 man-hours to assemble and  $\frac{1}{2}$  hour to repair) and inexpensive to construct, as well as, being very light and portable. It typically has a good high frequency response ( $\approx 100 \text{ MHz}$ ) and is able to withstand  $\approx 300 \text{ kV}$  without being immersed in oil. With a high input impedance ( $\approx 10 \text{ k}\Omega$ ), it is a tool that would be very useful in many research applications. The design of the probe is very similar to the one shown in Fig. 4a except that Velostat<sup>1</sup> replaces the inner resistor divider chain and the electrolyte. Velostat is a trade name for polyolefin plastic that is made conductive by the addition of carbon. No oil or electrolyte is used. Velostat film is available in 150 ft rolls of 4, 6, and 8 mil thicknesses and several widths (36-72 in). "Velostat layflat tubing" with 4 and 8 mil thicknesses and widths varying from 3 to 12 in can be purchased in 500 ft rolls. Solid rod stock has diameters from  $1/8$  to  $13/16$  in. Also, the top metal electrodes of Fig. 3c may be replaced by thin metal sheets since there are no oil or electrolyte reservoirs to seal. Even aluminum foil may be used for the electrodes; this allows their diameter,  $d_3$ , to be varied for fine tuning the probe response.

Table I contains a comparison of various sizes and styles of the new probe design. The parameters listed are the dimensions indicated in Fig. 4c plus the limiting risetimes ( $t_r$ ) of the different styles. The response of two of these probe styles (f),  $\approx 300 \text{ kV}$ , and (g),  $\approx 50 \text{ kV}$ , is compared to a calibrated input signal in Fig. 5. The inner Velostat cylinder of probe (f) will dissipate  $\approx 2 \text{ kJ}$  of energy with only a 10% change in resistance ( $\approx 10^\circ\text{C}$  change).

References

1. "Velostat" - Trade name for polyolefin plastic that is made conductive by the addition of carbon. 3M Co., Nuclear Products Dept., 3M Center, St. Paul, Minnesota 55101.
2. Henins, I., Progress Report No. LA-5656-PR, Los Alamos Scientific Laboratories, Los Alamos, New Mexico 87544, July, 1974.

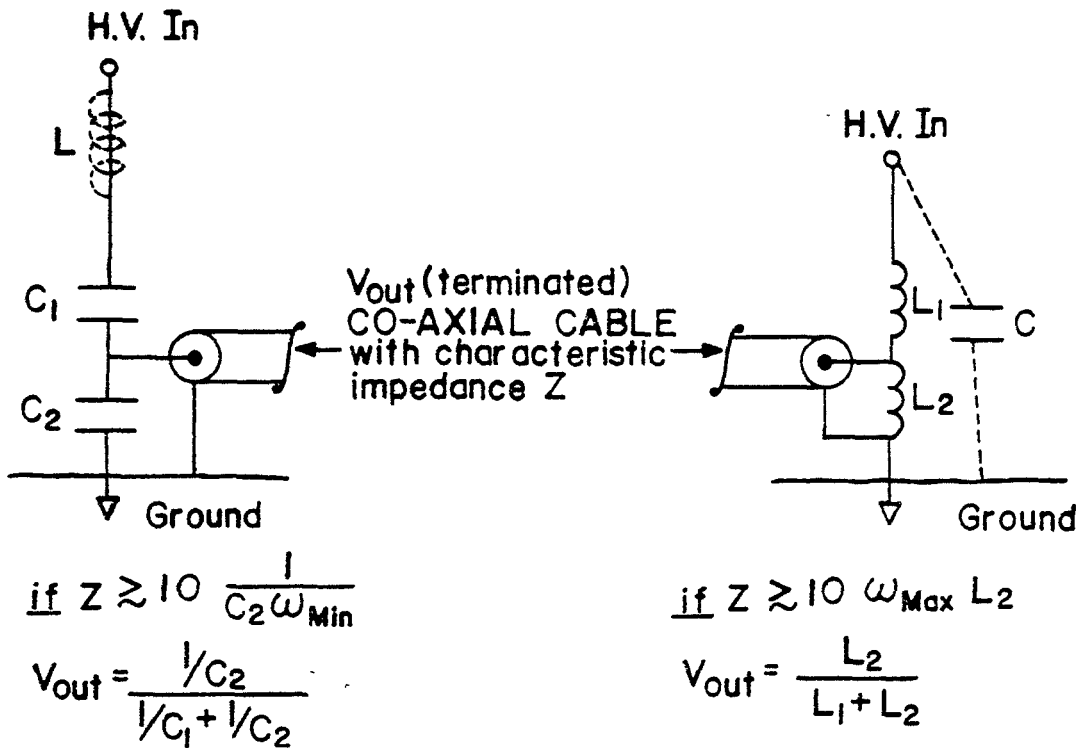
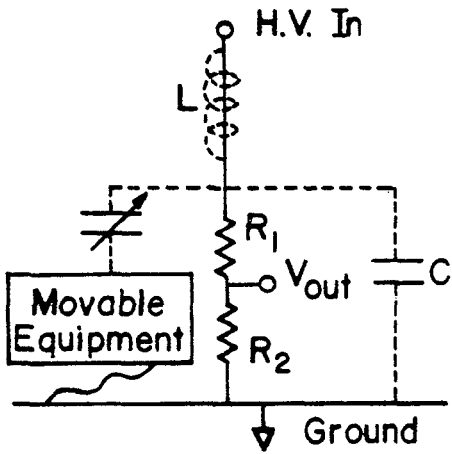


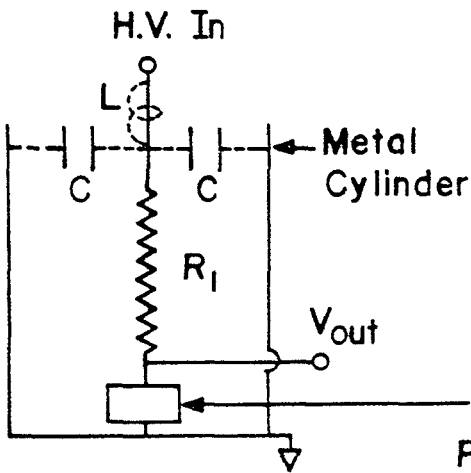
Fig. 1. Capacitive and inductive voltage divider chains.



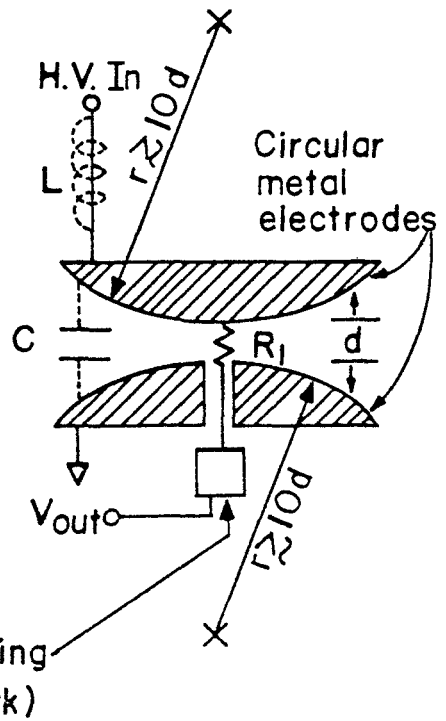
if  $R_1 + R_2 \lesssim \frac{1}{10} \frac{1}{\omega_{\text{Max}} C}$

$$V_{\text{out}} = \frac{R_2}{R_1 + R_2}$$

Fig. 2. Resistive divider chain.

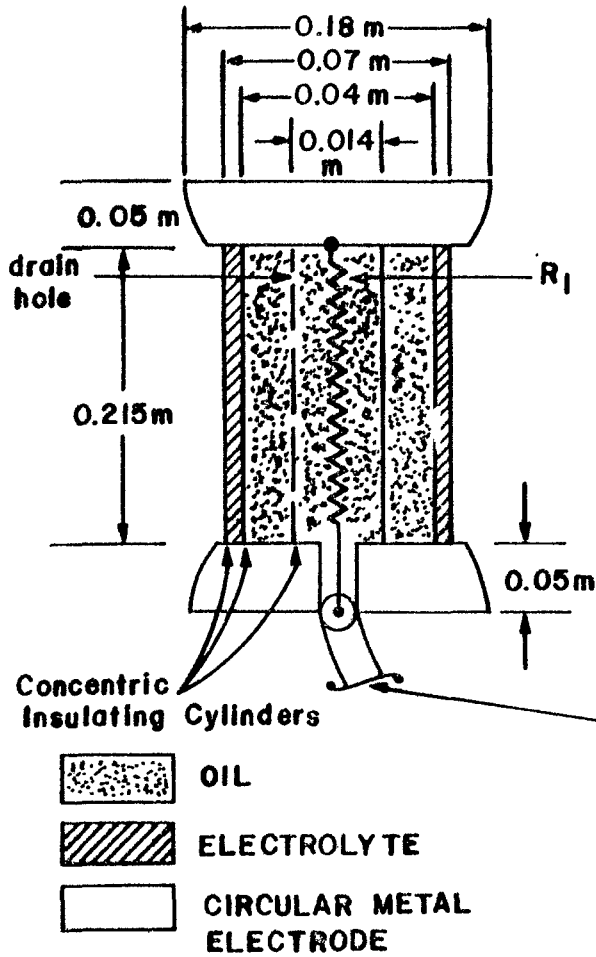


(a)

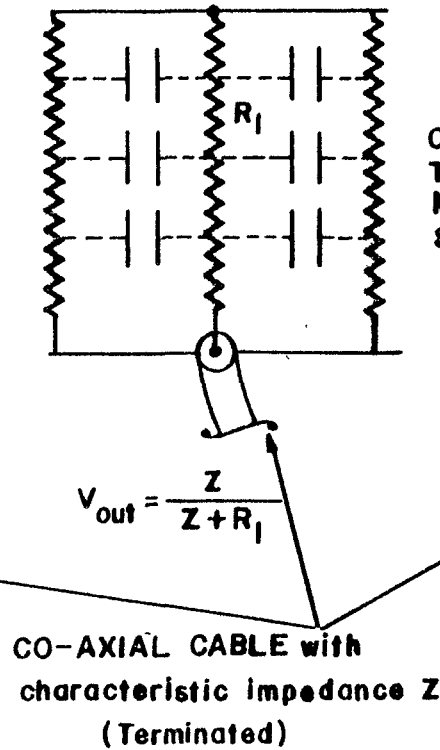


(b)

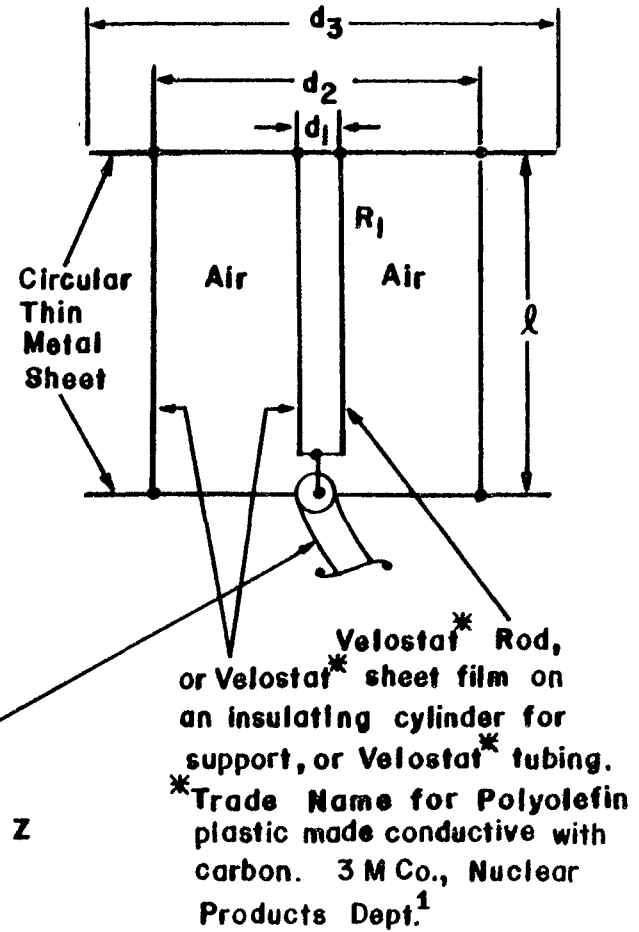
Fig. 3. Two methods of removing the variable capacitance in Fig. 2



(a) L.A.S.L. High Voltage Probe<sup>2</sup>



(b) Model of a. and b.



(c) High Voltage Probe made with Velostat.\*

Fig. 4. Preferred methods for HV probe design.

Approximate Dimensions	$d_1(m)$	$d_2(m)$	$d_3(m)$	$l(m)$	Risetime $t_r$	
H.V. Probe made with 8 mil Velostat <sup>1</sup> film $(\frac{V_{in}}{V_{out}} \approx 1,500:1 \rightarrow 3,000:1)$	(a)	0.089	none	none	1.	$\approx 3\mu S$
	(b)	0.089	0.091	none	1.	$\approx 300nS$
	(c)	0.089	0.091	$\sim 0.5$	1.	$\approx 200nS$
	(d)	0.027	0.089	0.089	1.	$\approx 100nS$
	(e)	0.027	0.089	$\sim 0.5$	1.	$\approx 50nS$
	(f)	0.027	0.16	$\sim 0.5$	1.	$\approx 20nS$
	(g)	0.007	0.06	0.06	0.2	$\approx 10nS$
L.A.S.L. H.V. Probe <sup>2</sup> $(\frac{V_{in}}{V_{out}} \approx 1,000:1 \rightarrow 2000:1)$	0.008	$\sim 0.035$	0.18	0.215	$\approx 10nS$	

Table I. Comparison of different probe styles.

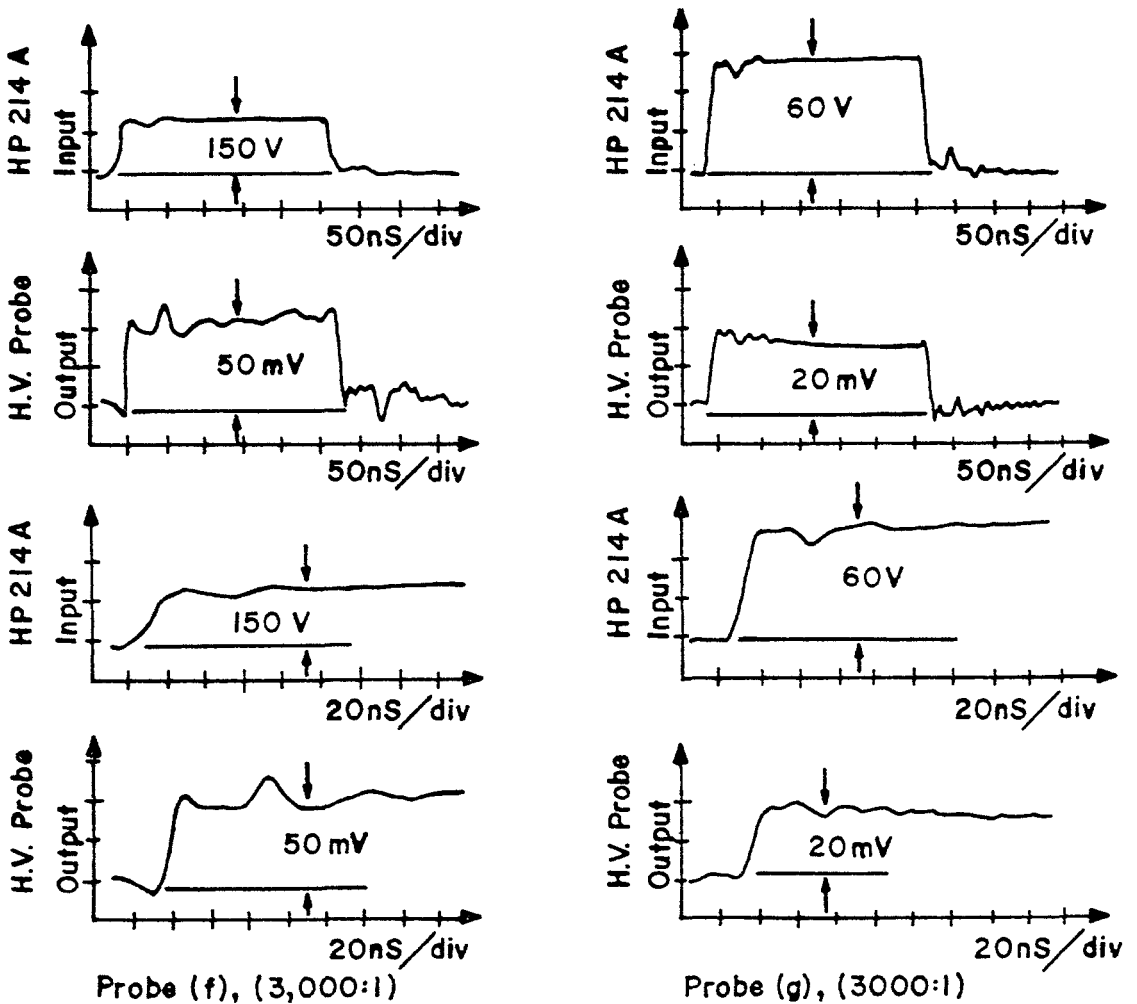


Fig. 5. Probe response to a calibrated input signal.