

## Length-independent voltage fluctuations in small conductors

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**Abstract.** The mean-squared voltage fluctuation of a disordered conductor of length  $L$  smaller than the phase coherence length  $L_\phi$ , is independent of the distance between the probes. We obtain this result using the voltage additivity and the known results for the conductance fluctuation. Our results complement the recent theoretical and experimental findings.

**Keywords.** Universal conductance fluctuations; phase coherence length.

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It has been shown both experimentally and theoretically that one can observe surprising, novel phenomena at low temperatures (Imry 1986a; Washburn and Webb 1986) in the quantum-transport regime, when the inelastic mean-free path  $L_\phi$  (or the phase-breaking length) of an electron is comparable to the size of the sample. It is now well established that these phenomena are consequences of coherent interference effects because of elastic scattering by impurities (static disorder). Elastic scattering causes phase randomization; however, electrons do not lose their phase memory. On the contrary, inelastic scattering leads to a loss of phase memory. In disordered systems the length over which an electron can retain its phase memory  $L_\phi$  can be much larger than the elastic mean-free path  $L_e$ . In certain disordered metals, at low temperatures ( $\approx 1$  K),  $L_\phi$  can be of the order of  $\mu\text{m}$  (or more depending on the resistance of the sample). Micron size devices have been fabricated using modern lithographic and electron-beam techniques. Some of the phenomena observed in these systems include (Washburn and Webb 1986) the normal state Aharonov-Bohm effect in disordered metallic rings, universal conductance fluctuations in metallic systems and the non-additivity and non-self-averaging nature of quantum ohmic resistance in thin disordered wires (Kumar and Jayannavar 1985).

Recently it has been shown experimentally (Benoit *et al* 1987) that the voltage fluctuations, of an ensemble of disordered conductors, measured between the two voltage probes (in a four-probe geometry) are independent of distance  $x$  between the probes, when  $x$  is less than  $L_\phi$ . The root-mean-squared (rms) value of these fluctuations is given by  $\Delta V_\phi = IR_\phi^2 (e^2/h)$ . Here  $I$  is the current flowing through the conductor and  $R_\phi$  the classical average resistance of the conductor of length  $L_\phi$ . When the voltage fluctuations are measured over a distance larger than  $L_\phi$ , then one can treat the system as if it is composed of independent subsystems of length  $L_\phi$ ; i.e., voltage fluctuations in different subsystems are uncorrelated. Hence the square of the voltage fluctuations is additive and we get  $\Delta V = \Delta V_\phi (L/L_\phi)^{1/2}$ , where  $\Delta V_\phi$  is the rms voltage fluctuation across a sample of length  $L_\phi$ . This is in conformity with the experimental results (Washburn