Origin of 1/f magnetic noise in superconducting circuits

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We analyze theoretically a possible origin of the recently observed 1/f noise in the complex inductance of SQUIDs. The experimental data indicate a large cross-correlation of the inductance noise with the usual flux noise which is the dominant cause of decoherence in flux and phase qubits. Understanding of this phenomena sheds a new light on the long standing problem of 1/f flux noise in superconducting circuits. Our analysis shows that in SQUIDs with relatively small loops (under 1 micron) the inductance noise is dominated by the kinetic inductance fluctuations due to the dynamics of charged impurities; whereas in SQUIDs with large loops (much larger 1 micron) the inductance noise is dominated by magnetic coupling of the loop to a system of unpaired spins localized on the surface of the superconducting wires. Moreover, we argue that the cross-correlations in the magnetic noise observed in large SQUIDs (perimeter of order of 100 micron) imply a formation of long range order in fractal spin structures on the surface of the superconducting wiring. We show that such structures appear naturally in a random system of spins with wide distribution of spin-spin interactions; and that the fractal nature of this ferromagnetic state manifests in $1/f^{1+\zeta}$ spectra of magnetization noise, with small exponent ζ, and large cross-correlations in the magnetic noise which reproduce inductance-flux cross-correlations observed in SQUIDs.