We present a theoretical and experimental study of spin precession in the presence of both a static and an orthogonal oscillating magnetic field, which is nonresonant, not harmonically related to the Larmor precession, and of arbitrary strength. Due to the intrinsic nonlinearity of the system, previous models that account only for the simple sinusoidal case cannot be applied. We suggest an alternative approach and develop a model that closely agrees with experimental data produced by an optical-pumping atomic magnetometer. We demonstrate that an appropriately designed nonharmonic field makes it possible to extract a linear response to a weak dc transverse field, despite the scalar nature of the magnetometer, which normally causes a much weaker, second-order response.