$$\vec{S}'' = \begin{pmatrix} (S\sin^2\theta\cos\omega t + S\cos^2\theta)\cos\omega_1 t + S\sin\theta\sin\omega t\sin\omega_1 t \\ -(S\sin^2\theta\cos\omega t + S\cos^2\theta)\sin\omega_1 t + S\sin\theta\sin\omega t\cos\omega_1 t \\ S\sin\theta\cos\theta(\cos\omega t - 1) \end{pmatrix}$$

Let $\omega_1 t = \alpha$

Let $k = \dfrac{\gamma B_1}{\omega_1}$

Then

$$\sin\theta = \frac{\omega_1}{\gamma B_{eff}} = \frac{\omega_1}{\omega} = \frac{\omega_1}{\sqrt{(\gamma B_1)^2 + \omega_1^2}} = \frac{1}{\sqrt{k^2+1}}$$

$$\cos\theta = \frac{B_1}{B_{eff}} = \frac{\gamma B_1}{\sqrt{(\gamma B_1)^2 + \omega_1^2}} = \frac{k}{\sqrt{k^2+1}}$$

$$\omega t = (\omega_1 t)\frac{\omega}{\omega_1} = \alpha \cdot \sqrt{k^2+1}$$

Thus,

$$\vec{S}'' = \begin{pmatrix} \left(S\left(\frac{1}{\sqrt{k^2+1}}\right)^2\cos(\alpha\sqrt{k^2+1}) + \frac{k^2}{k^2+1}\right)\cos\alpha + S\frac{1}{\sqrt{k^2+1}}\sin(\alpha\sqrt{k^2+1})\sin\alpha \\ -\left(S\frac{1}{k^2+1}\cos(\alpha\sqrt{k^2+1}) + S\frac{k^2}{k^2+1}\right)\sin\alpha + S\frac{1}{\sqrt{k^2+1}}\sin(\alpha\sqrt{k^2+1})\cos\alpha \\ S\frac{k}{k^2+1}\left(\cos(\alpha\sqrt{k^2+1}) - 1\right) \end{pmatrix}$$