The denominator can be written as

$$\begin{aligned}
||\vec{x}+\alpha\vec{e}_1||_2^2 &= \sqrt{\langle \vec{x}+\alpha\vec{e}_1, \vec{x}+\alpha\vec{e}_1\rangle}^2 \\
&= \langle \vec{x}+\alpha\vec{e}_1, \vec{x}+\alpha\vec{e}_1\rangle \\
&= \langle \vec{x}+\alpha\vec{e}_1, \vec{x}\rangle + \langle \vec{x}, \alpha\vec{e}_1\rangle + \langle \alpha\vec{e}_1, \alpha\vec{e}_1\rangle \\
&= \langle \vec{x}+\alpha\vec{e}_1, \vec{x}\rangle + \langle \vec{x}, \alpha\vec{e}_1\rangle + \alpha^2 \\
&= \langle \vec{x}+\alpha\vec{e}_1, \vec{x}\rangle + \langle \vec{x}, \alpha\vec{e}_1\rangle + ||\vec{x}||_2^2 \\
&= \langle \vec{x}+\alpha\vec{e}_1, \vec{x}\rangle + \langle \vec{x}, \alpha\vec{e}_1\rangle + \langle \vec{x}, \vec{x}\rangle \\
&= \langle \vec{x}+\alpha\vec{e}_1, \vec{x}\rangle + \langle \vec{x}, \vec{x}+\alpha\vec{e}_1\rangle \\
&= 2\left\langle \vec{x}+\alpha\vec{e}_1, \vec{x}\right\rangle,
\end{aligned}$$