$\exists\ 0 \le A_\infty < \infty$ s.t. $A_n \to A_\infty$. Moreover,

(*) $A_{2n} \le A_\infty \le A_{2n-1}$

since $A_1 \ge A_3 \ge \cdots$

Consequently

$$|A_\infty - A_n| \le b_{n+1}.$$