

51. We denote the speed of the French submarine by u_1 and that of the U.S. sub by u_2 .

(a) The frequency as detected by the U.S. sub is

$$f'_1 = f_1 \left(\frac{v + u_2}{v - u_1} \right) = (1000 \text{ Hz}) \left(\frac{5470 + 70}{5470 - 50} \right) = 1.02 \times 10^3 \text{ Hz} .$$

(b) If the French sub were stationary, the frequency of the reflected wave would be $f_r = f_1(v + u_2)/(v - u_2)$. Since the French sub is moving towards the reflected signal with speed u_1 , then

$$\begin{aligned} f'_r &= f_r \left(\frac{v + u_1}{v} \right) = f_1 \frac{(v + u_1)(v + u_2)}{v(v - u_2)} \\ &= \frac{(1000 \text{ Hz})(5470 + 50)(5470 + 70)}{(5470)(5470 - 70)} \\ &= 1.04 \times 10^3 \text{ Hz} . \end{aligned}$$