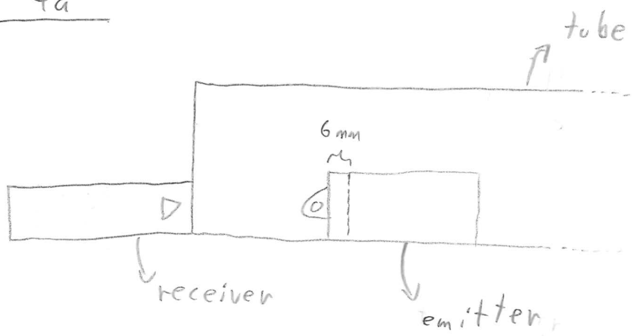
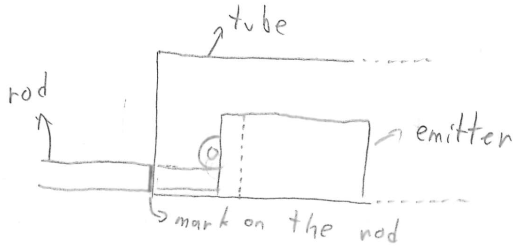
Student: HRV-S5

Sheet: E-001

Side: A

## Task 4a




To place the transmitter at a set distance z from the end of the tube, i pushed it in with the wooden stick on which I had made a mark at the required distane with a pencil. When the mark reached the end of the tube, the transmitter was at the connect position. I also compensated for the fact the transmitter is 6 mm away from the edge of its case. That way z is the distance from the wave source to the edge of the tube.

| z / mm | $P_{dBm}$ | P / W | ln (P/W) |
|---|---|---|---|
| 20 | -33 | $5.01 \cdot 10^{-7}$ | -14.5 |
| 30 | -41 | $7.94 \cdot 10^{-8}$ | -16.3 |
| 40 | -47 | $2.00 \cdot 10^{-8}$ | -17.7 |
| 50 | -56 | $2.51 \cdot 10^{-9}$ | -19.8 |
| 75 | -77 | $2.00 \cdot 10^{-11}$ | -24.6 |
| 100 | -99 | $1.26 \cdot 10^{-13}$ | -29.7 |

$$P_{dBm} = 10 \log_{10} \frac{P}{mW}$$

$$10^{P_{dBm}} = 10^{10 \log_{10} \frac{P}{mW}} = \left(\frac{P}{mW}\right)^{10}$$

$$P = 10^{\frac{P_{dBm}}{10}} mW = \frac{10^{\frac{P_{dBm}}{10}}}{1000} W = 10^{\frac{P_{dBm}}{10} - 3} W$$

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Sheet: E-001

Side: B

Task 4a (cont.)

A plot of $\ln\left(\frac{P}{W}\right)$ vs z is on sheet E-016, side A. A linear Fit has been made through the points.

$\vec{E} = \vec{E_0}(r,\varphi)\, e^{-\alpha z} e^{i(kz-\omega t)}$ $\quad \alpha = 0$ for air, $k = i\mu$

$\vec{E} = \vec{E_0}(r,\varphi)\, e^{-\mu z - i\omega t}$

$P \propto |E|$

$\Downarrow$

$P = P_0 e^{-\mu z} \quad /:W$

$\frac{P}{W} = \frac{P_0}{W} e^{-\mu z}$

$\ln\left(\frac{P}{W}\right) = \ln\left(\frac{P_0}{W}\right) - \mu z$

$A(0\,m, -10.1)$
$B(0.1\,m, -29.5)$ } points on the linear fit

$-10.1 = \ln\left(\frac{P_0}{W}\right)$

$\ln\left(\frac{P}{W}\right) = -10.1 - \mu z$

$-29.5 = -10.1 - 0.1\mu$

$-0.1\mu = -19.4$

$\boxed{\mu = 194}$

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Sheet: E-002

Side: A

Task 4b

I conducted the experiment in the same way as in 4a., using tubes with diameters of 41 mm, 59 mm and 100 mm, but I measured only with $z_1 = 50$ mm and $z_2 = 100$ mm

I hypothesise $\mu$ will decrease as d increases, because there is a larger area for the waves to travel through.

| d / mm | $P_{dBm}(z_1 = 50\ mm)$ | $P_{dBm}(z_2 = 100\ mm)$ | $\mu / m^{-1}$ |
|---|---|---|---|
| 41 | -58 | -107 | 226 |
| 59 | -55 | -87 | 147 |
| 100 | -43 | -63 | 92.1 |
| 46 | -56 | -99 | 194* |

$$P_1 = 10^{\frac{P_{dBm}(z_1 = 50\ mm)}{10} - 3}\ W$$

$$P_2 = 10^{\frac{P_{dBm}(z_2 = 100\ mm)}{10} - 3}\ W$$

* calculated previously using a different method, see sheet E-001, side B

$$\ln\left(\frac{P_1}{W}\right) = \ln\left(\frac{P_0}{W}\right) - \mu z_1$$

$$\ln\left(\frac{P_2}{W}\right) = \ln\left(\frac{P_0}{W}\right) - \mu z_2$$

$$\ln\left(\frac{P_1}{W}\right) - \ln\left(\frac{P_2}{W}\right) = \mu z_2 - \mu z_1$$

$$\ln\left(\frac{P_1}{P_2}\right) = \mu(z_2 - z_1)$$

$$\mu = \frac{\ln\left(\frac{P_1}{P_2}\right)}{z_2 - z_1}$$

A plot of $\mu$ vs d is shown on sheet E-016, side B

My hypothesis was proven with this experiment.

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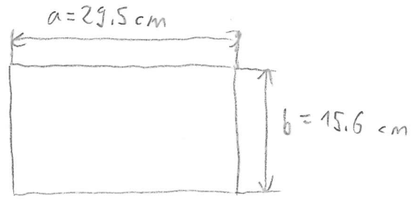
Sheet: E-003
Side: A

Task 2.

| d / mm | $P_{dBm}$ |
|---|---|
| 6.5 | -48 |
| 8.7 | -58 |
| 10.9 | -56 |
| 13.0 | -61 |
| 15.2 | -57 |
| 16.3 | -62 |
| 17.4 | -55 |
| 18.5 | -57 |
| 20.6 | -62 |
| 22.8 | -47 |
| 23.9 | -(46) |
| 25.0 | -49 |
| 27.2 | -52 |
| 29.3 | -55 |
| 33.7 | -56 |
| 38.0 | -54 |
| 42.4 | -48 |
| 44.6 | -(45) |
| 47.7 | -47 |
| 48.9 | -49 |
| 51.1 | -55 |

I used the setup from Figure 2., with the detector placed on the lid, directly above the transmitter and always in the same place.

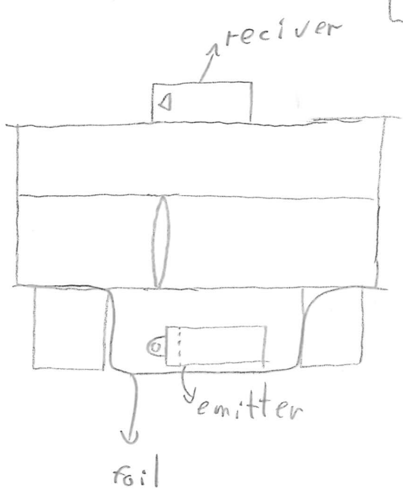
I measured the volume of water added using the jug and calculated the water depth d using the dimensions of the box.




$A = ab$

$V = dA = dab$

$$d = \frac{V}{ab}$$




A standing wave can appear in the water, in which case the amplitude will be amplified.

$d = n \cdot \frac{\lambda}{2}, \quad n \in \mathbb{N}$

The water depth must be a whole number mutiple of $\frac{\lambda}{2}$ for a standing wave to appear.

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Sheet: E-003

Side: B

Task 2. (cont.)

Two distinct peaks are visible in the data (circled). The corresponding depths must be $\frac{\lambda}{2}$ apart, and the first peak must be at depth $\frac{\lambda}{2}$.

$d_1 = 23.9\ mm = 0.0239\ m$

$d_2 = 44.6\ mm = 0.0446\ m$

$d_1 = \frac{\lambda_1}{2}$ $\lambda_1 = 0.0478\ m$

$d_2 = \lambda_2$ $\lambda_2 = 0.0446\ m$

$$\lambda = \frac{\lambda_1 + \lambda_2}{2} = 0.0462\ m = 46.2\ mm$$

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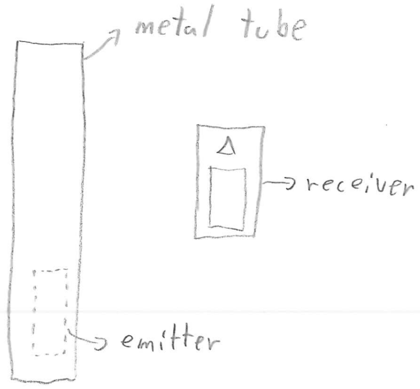
Sheet: E-004

Side: A

## Task 1.




I put the emitter in a metal tube to block most of the radio waves, and than moved the receiver as far away as possible to still get a reading on it. The lowest possible reading was 129 dBm.

$P_{dBm} = -129$

$P = 10^{\frac{P_{dBm}}{10}}$ mW

$\boxed{P = 1{,}26 \cdot 10^{-13} \text{ mW}}$

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Sheet: E-016

Side: A