Ground-Penetrating Radar for Fiber Duct Localisation

Radar & Remote Sensor

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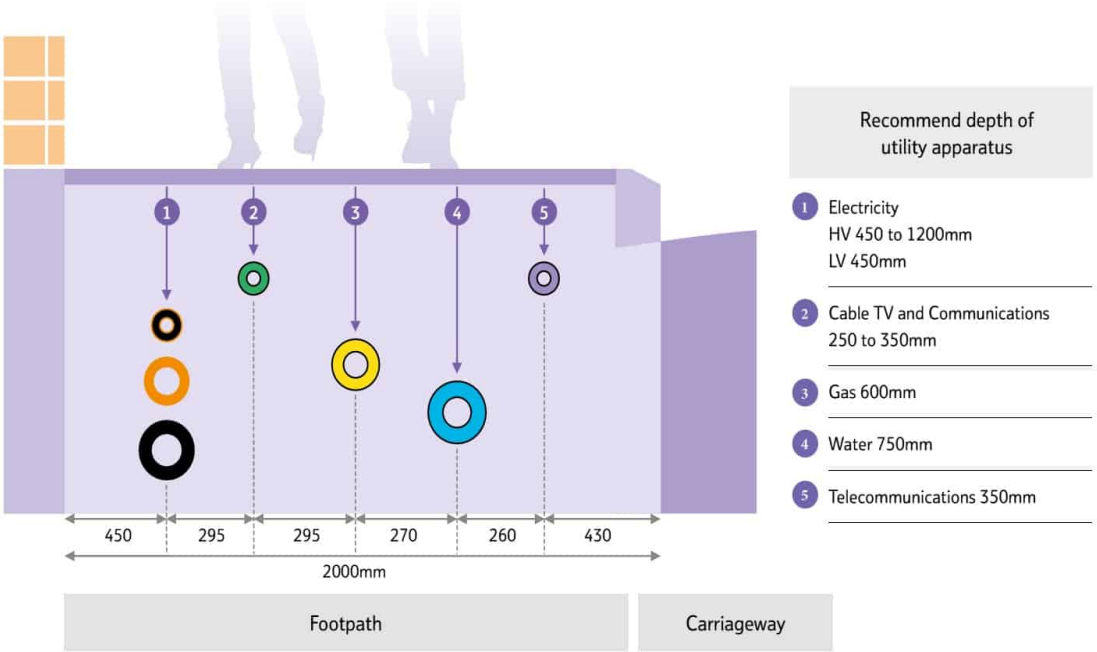
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Objective

Finding the location and giving a possible identification of the ducts.





Application Description and Requirements

Form Factor & Cost

- Compact and lightweight for deployment in the field.
- Low cost components that can be found in the current market to supply the manufacturing.

Resolution & Power consumption

- Ability to distinguish between different lateral targets that are 20 cm separated
- Power consumption that is reasonable for a days worth of work



Introduction

How should we model a Ground penetrating radar ?
Model - National Bureau of Standards (NBS)

$$P_R = \frac{P_t G_t G_r \lambda^2 \sigma}{(4\pi)^3 R^4} ICDe^{-4\alpha R}$$

- I = two-way power transmission at the air/soil interface, accounting for dielectric differences.
- D = dispersion effect due to the medium resulting in pulse stretch and subsequent amplitude reduction
- C = factor accounting for the two-way refraction at the air/soil interface.
- α = the attenuation factor of the complex propagation constant.

Radar system implementation

Propagation Medium - Air VS Solid

$$\alpha = w\sqrt{\mu\epsilon}\left[\frac{1}{2}\left(\sqrt{1+\left(\frac{\sigma'}{w\epsilon}\right)^2}\right)+1\right]^{\frac{1}{2}}$$

Material	ϵ_r
Air	1
Seawater	81
Dry Sand	5
Dry Granite	7
Soil	2-20
Dry Cracked concrete	4-5
Asphalt	12-16

TABLE – Typical relative Dielectric constant for selected materials

Signal Noise Ratio

Thermal Noise

$$P_n = kT_sB$$

Received signal

$$SNR = \frac{P_t G^2 \lambda^2 \sigma}{(4\pi)^3 R^4 kT_s B} Ie^{-4\alpha R}$$

Antenna effective Area

$$PG^2 = 43.13 \rightarrow G = \frac{4\pi A_e}{\lambda^2} = \sqrt{\frac{43.13}{P}}$$

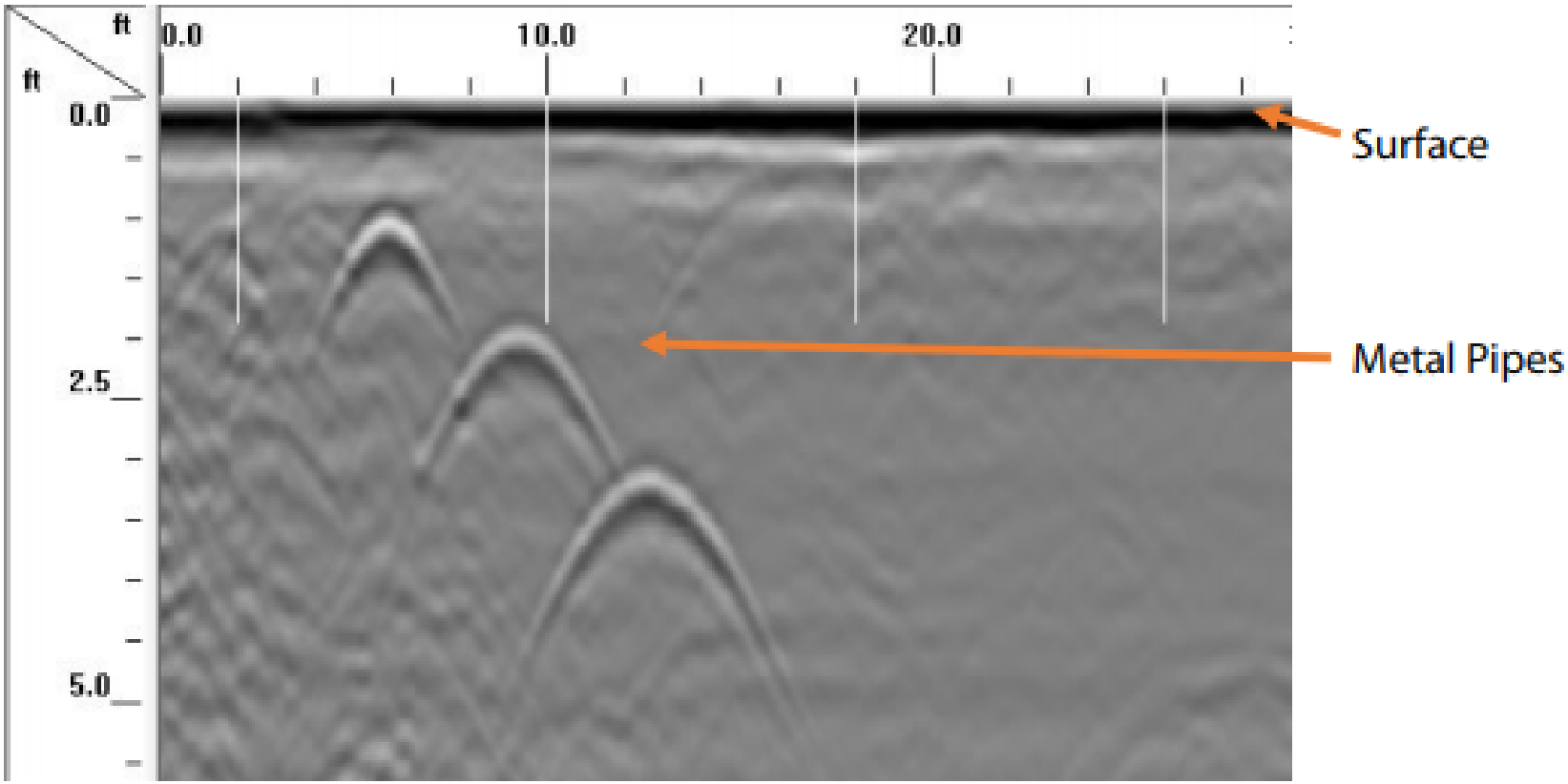
System parameters

- Material & Air/Soil interface dependence : D = C = 1, I = 0.48 , $\alpha = 2.3 \frac{dB}{m}$, n = 3.46
- Radar system parameters : f = 400 MHz, $\lambda = 0.217\ m$, B = 4 GHz
- Ideal cylinder Cross Section : $\sigma \approx R\pi a \approx 0.2\ m^2$ where R=2 m and a=32 mm
- Effective Area $A_e = 0.275\ m^2$

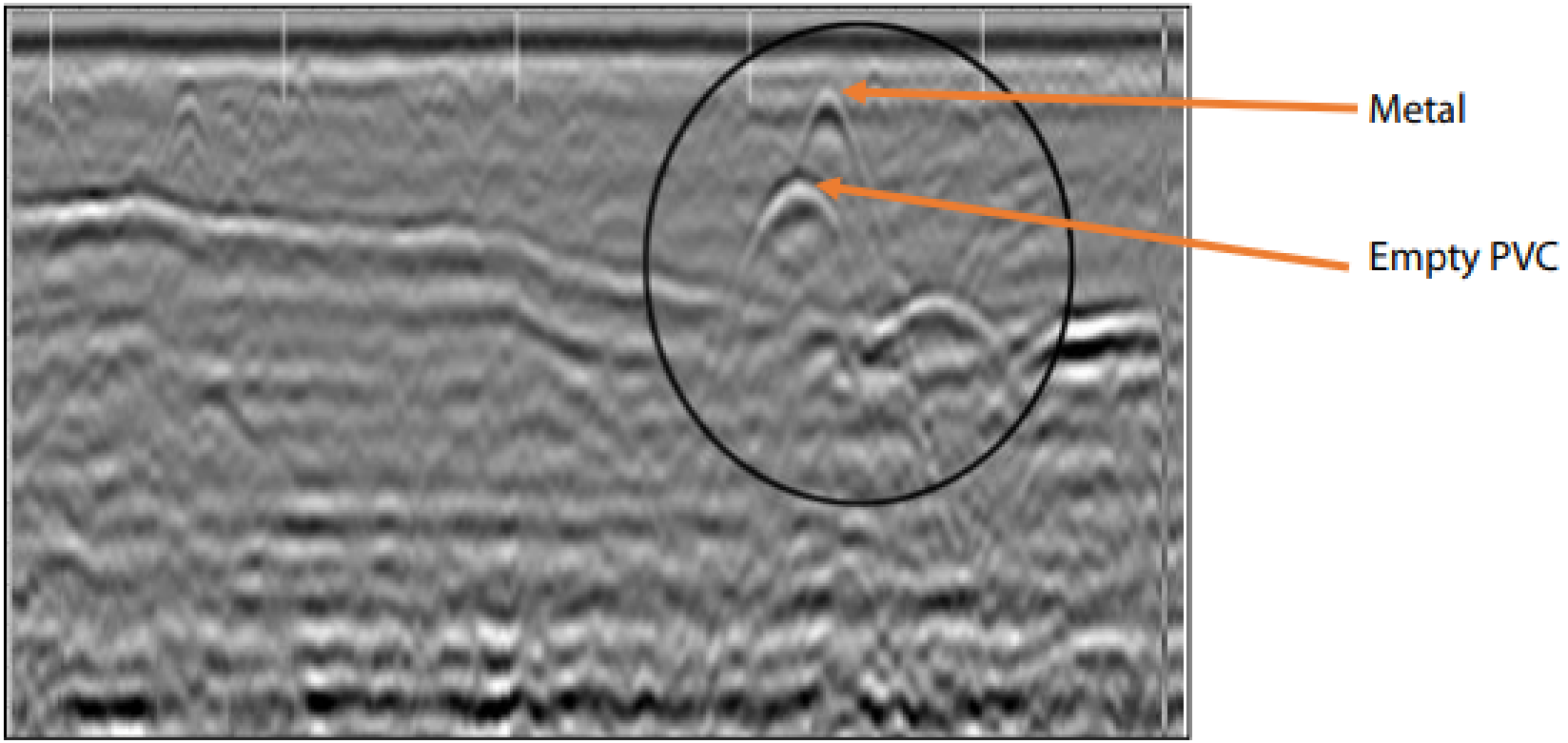
Resolution & Power

- ΔR= 15 cm, ΔCR = 10 cm
- 40 mW average signal power
- High power DC voltage, 8 W power consumption

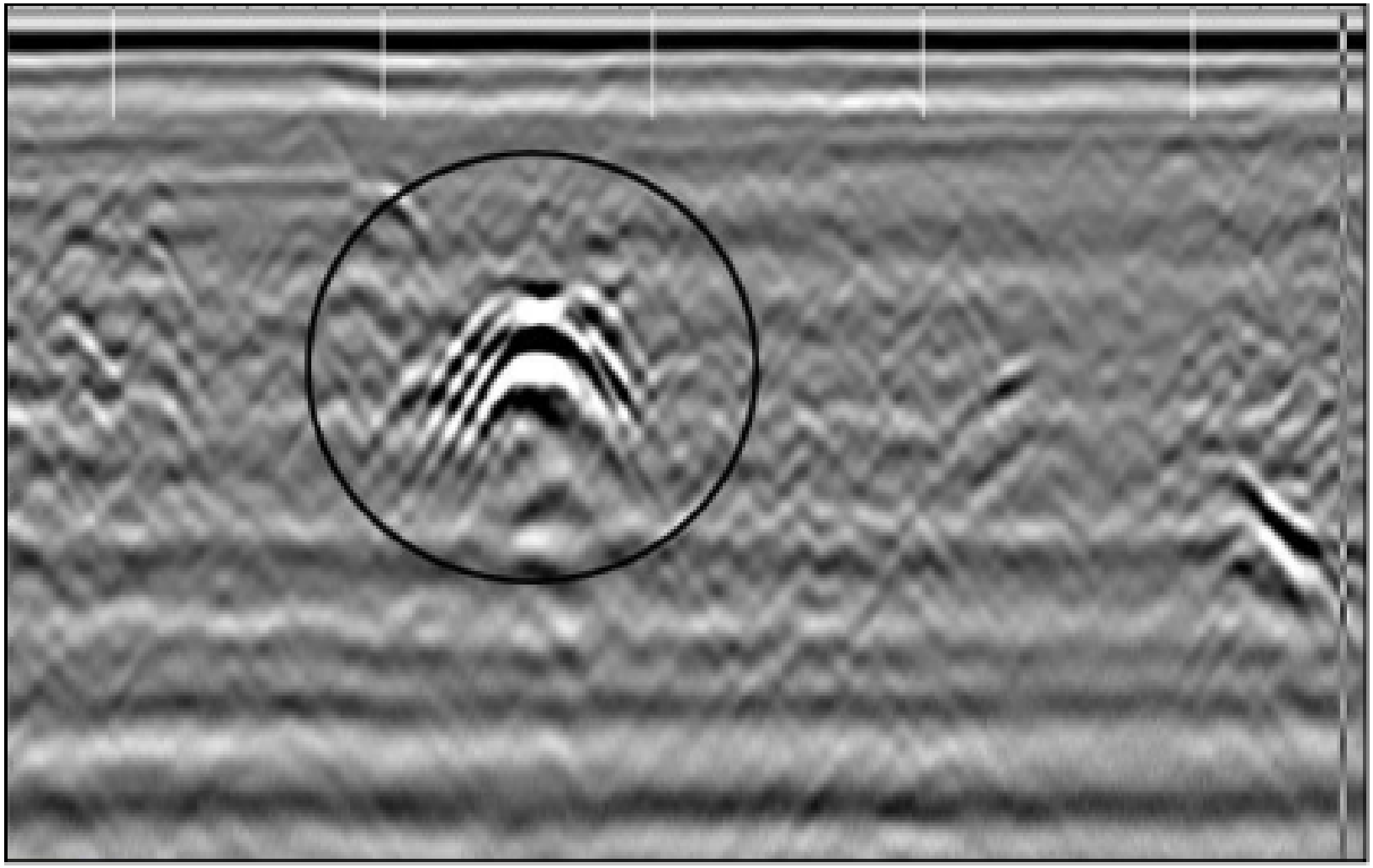
Metal ducts at different depths



PVC - Metal ducts



PVC with multiple cables inside.



Conclusions

- The system could effectively distinguish the location of the ducts and give off information about an approximate range.
- The size and power consumption could be fit for commercial implementation.
- Detection of the inside of the ducts could be possible due to cluttered signal.
- A trained operator make this system more useful since it requires image interpretation and filed correction.