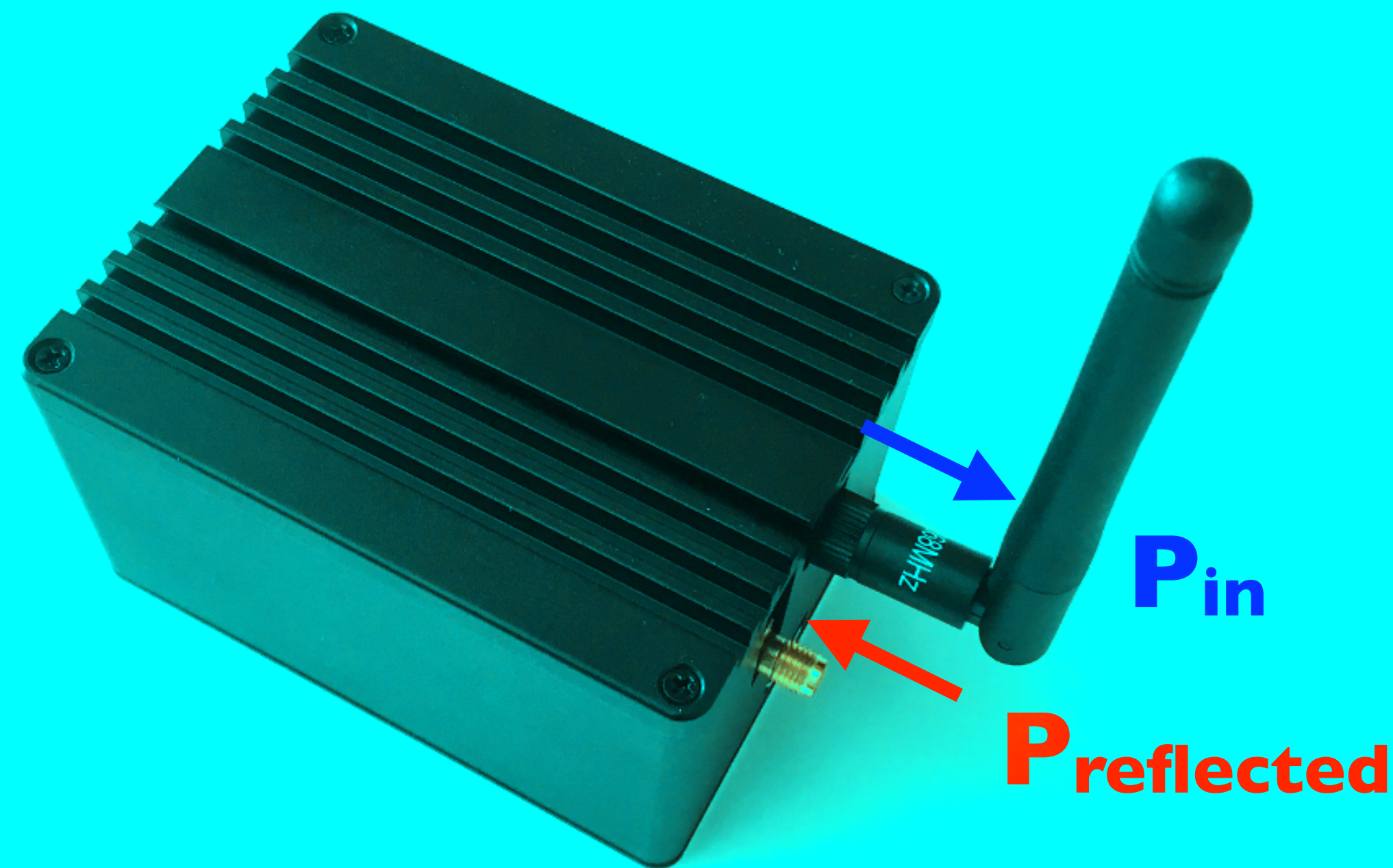


LORA / LORAWAN TUTORIAL 33

USWR or SWR and Reflection Coefficient or S11

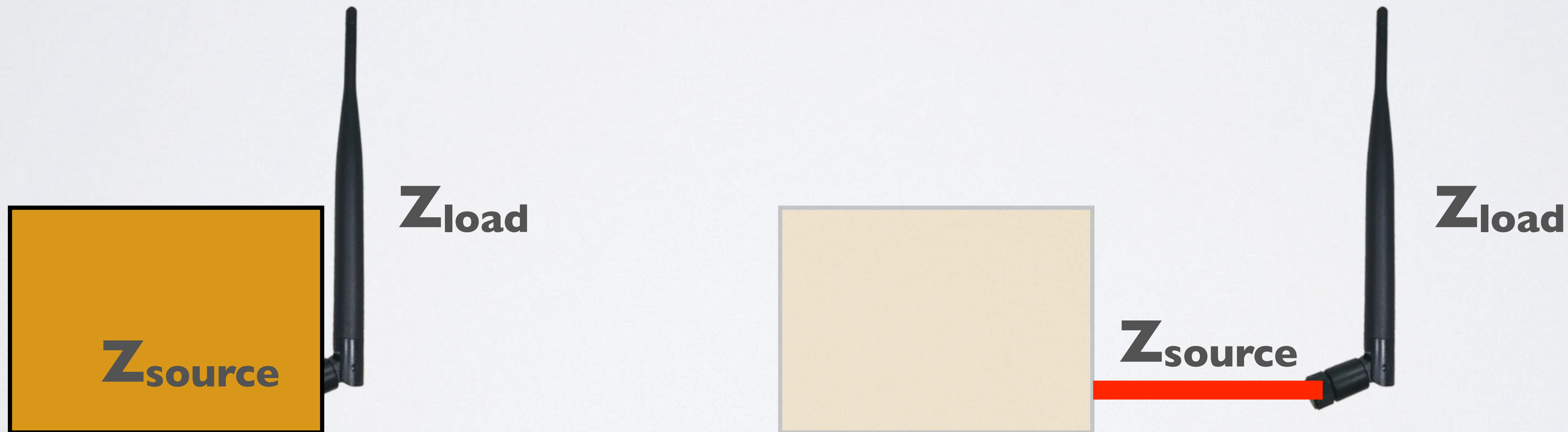


INTRO

- The parameters SWR and S I I are often used to judge the antenna performance.
- In this tutorial I will explain what these two parameters are.

VSWR / SWR

- The Voltage Standing Wave Ratio (VSWR), pronounced “viswar”, often referred to as SWR is how much of the power offered to the antenna is reflected back. It is the ratio of power offered to power reflected.
- This is the same as how well the antenna impedance (Z_{load}) is matched to the source (Z_{source}) it is connected to.



REFLECTION COEFFICIENT / $S|I$ AND VSWR

- **The reflection coefficient (Γ) is also known as $S|I$.**

- Formulas for reflection coefficient (Γ) and VSWR

$$\Gamma = \frac{Z_L - Z_s}{Z_L + Z_s} \quad \text{VSWR} = \frac{1 + |\Gamma|}{1 - |\Gamma|}$$

- Z_L is the load impedance [Ω], for example the antenna.
 Z_s is the source impedance [Ω], for example the gateway the antenna is attached to.
- The reflection coefficient values: $-1 \leq \Gamma \leq 1$
 The VSWR values: $\text{VSWR} \geq 1$

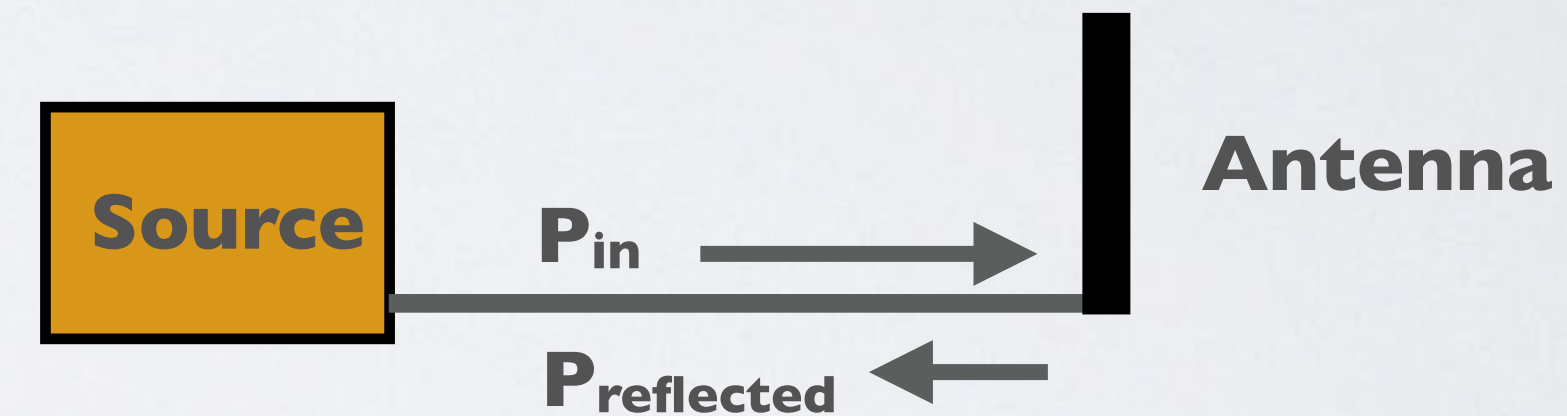
REFLECTION COEFFICIENT / S I I AND VSWR

- A VSWR = 1, no power is reflected (ideal situation), that is what we want.

$$\Gamma = \frac{Z_L - Z_s}{Z_L + Z_s} \quad \text{VSWR} = \frac{1 + |\Gamma|}{1 - |\Gamma|}$$

RETURN LOSS

- Formula for return loss (RL): **$RL \text{ (dB)} = -20 \log_{10} (\Gamma)$**
- Return loss is how much of the input power is reflected back and it is measured in dB. If a return loss is 20 dB, it means -20 dB.



- If $RL = 0 \text{ dB}$: It means 0 dB, the ratio is 1, 100% of P_{in} is reflected back.
 - If $RL = 3 \text{ dB}$: It means -3 dB, the ratio is 0.5, 50% of P_{in} is reflected back.
 - If $RL = 10 \text{ dB}$: It means -10 dB, the ratio is 0.1, 10% of P_{in} is reflected back.
 - If $RL = 20 \text{ dB}$: It means -20 dB, the ratio is 0.01, 1% of P_{in} is reflected back.
 - If $RL = 30 \text{ dB}$: It means -30 dB, the ratio is 0.001, 0.1% of P_{in} is reflected back.
- A higher return loss value results in a better antenna performance.

REFLECTION COEFFICIENT, VSWR AND RETURN LOSS

- Example: $Z_{\text{load}} = 60\Omega$ and $Z_{\text{source}} = 50\Omega$

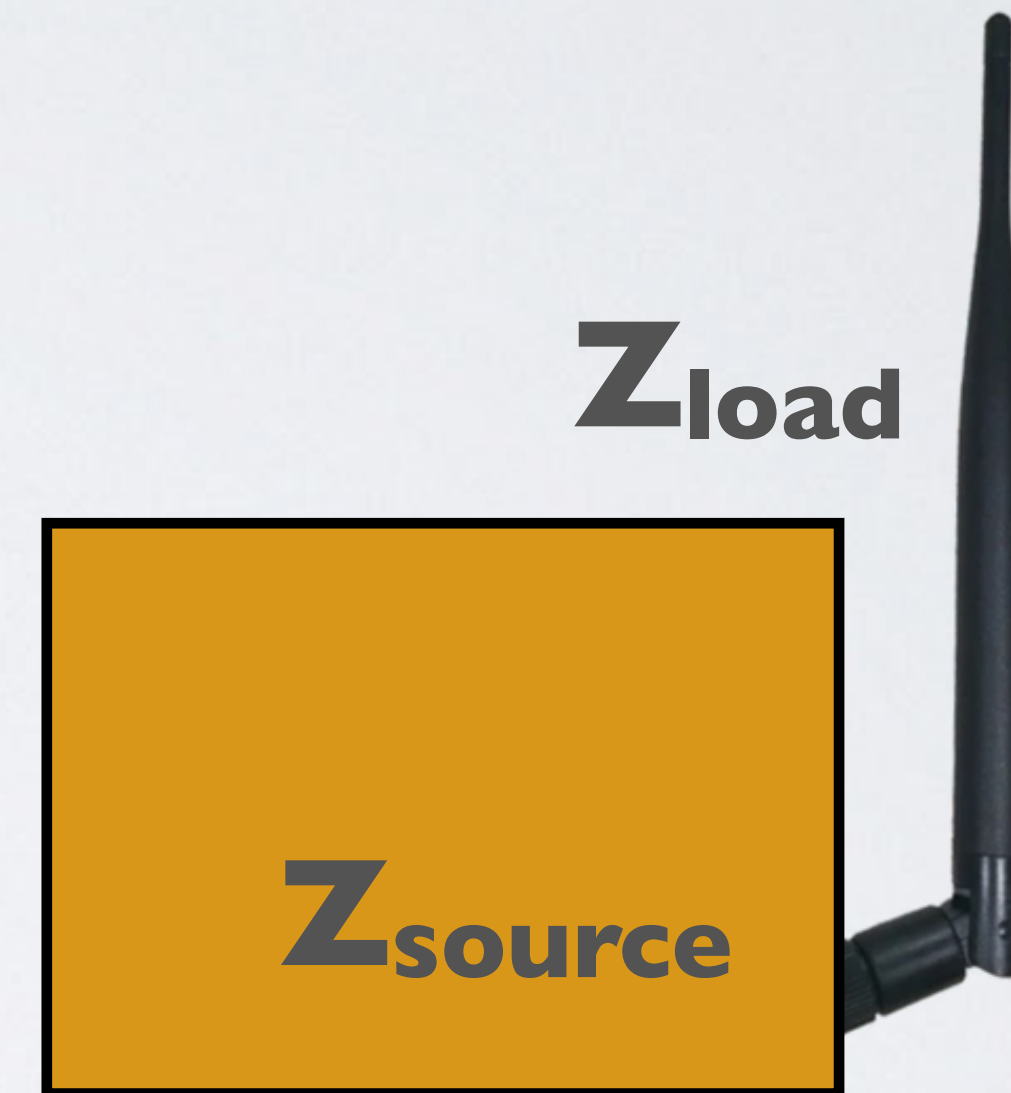
$$\Gamma = \frac{Z_L - Z_s}{Z_L + Z_s} = \frac{60 - 50}{60 + 50} = \mathbf{0.0909}$$

$$\mathbf{VSWR} = \frac{1 + |\Gamma|}{1 - |\Gamma|} = \frac{1 + |\mathbf{0.0909}|}{1 - |\mathbf{0.0909}|} = \mathbf{1.2}$$

$$\mathbf{RL} = -20 \log_{10} (\Gamma)$$

$$\mathbf{RL} = -20 \log_{10} (\mathbf{0.0909}) = \mathbf{20.83 \text{ dB}}$$

- Convert deciBel to power ratio = $10^{(\text{RL}/10)} = 10^{(-20.83/10)} = 0.0083$
This means 0.83% of the input power is reflected back.



VSWR

- In an **ideal** situation when no power is reflected back, ($Z_L = Z_S$) the VSWR = 1.0 or as commonly expressed as a ratio of 1:1.

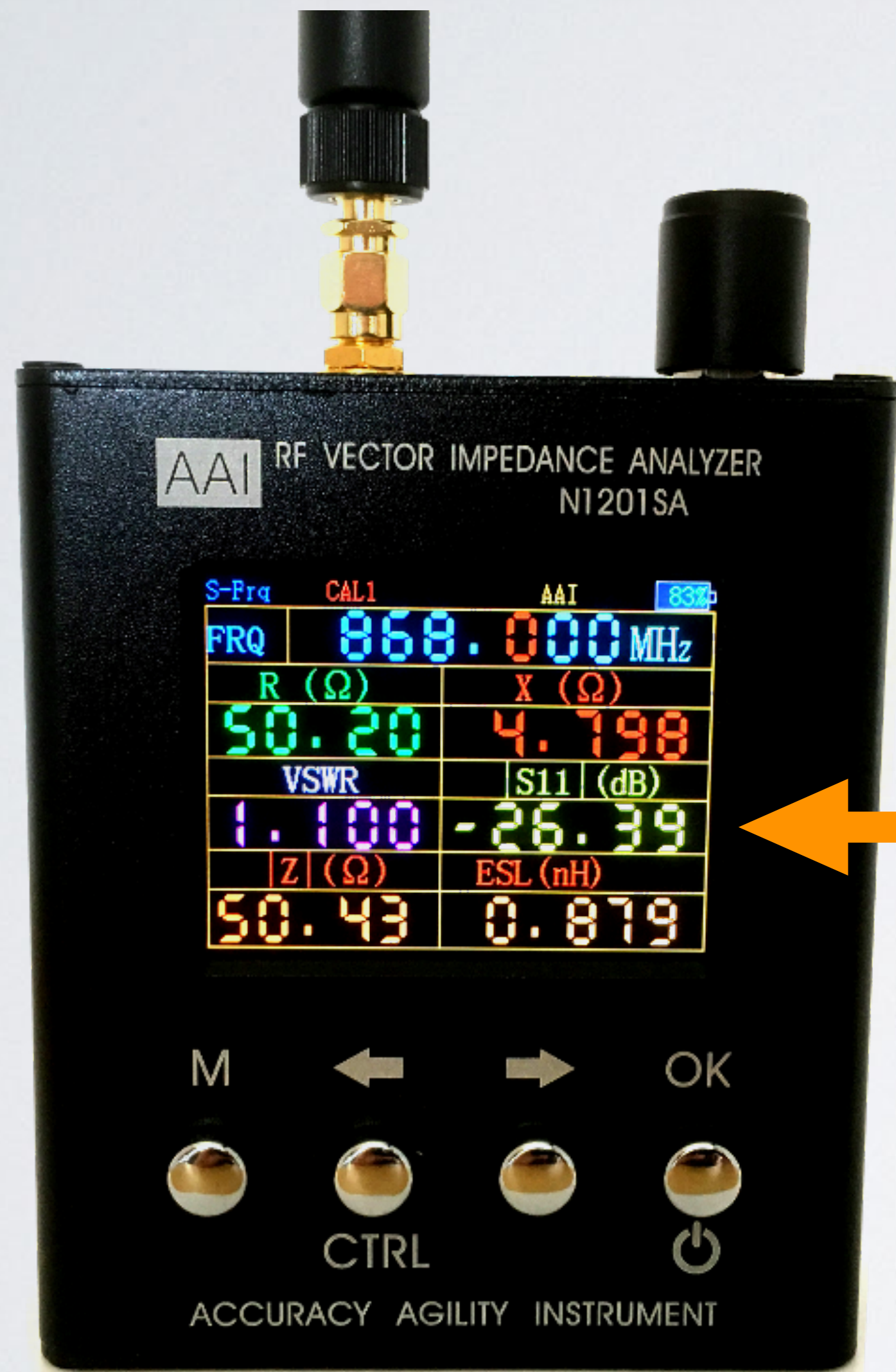
$$\Gamma = \frac{Z_L - Z_S}{Z_L + Z_S} \quad \mathbf{VSWR} = \frac{1 + |\Gamma|}{1 - |\Gamma|} \quad \Gamma = \frac{\mathbf{VSWR} - 1}{\mathbf{VSWR} + 1}$$

- The higher the impedance mismatch, the higher the VSWR value.
If $Z_S < Z_L$ than power is reflected back, for example VSWR = 1.4 or 1.4:1.
- An antenna with a VSWR \leq 1.4 is considered to be an excellent antenna.**
If VSWR = 1.4 than $\Gamma = 0.1667$ and RL = 15.56 dB
2.8% of the input power is reflected back.

$$\mathbf{RL (dB) = -20 \log_{10} (\Gamma)}$$

$$\mathbf{power\ ratio = 10^{(RL/10)}}$$

WELL OPTIMISED ANTENNA



This is a well optimised antenna.

VSWR = 1.1

S11 = -26.39 dB

Z = 50.43 Ω

VSWR AND REFLECTED POWER

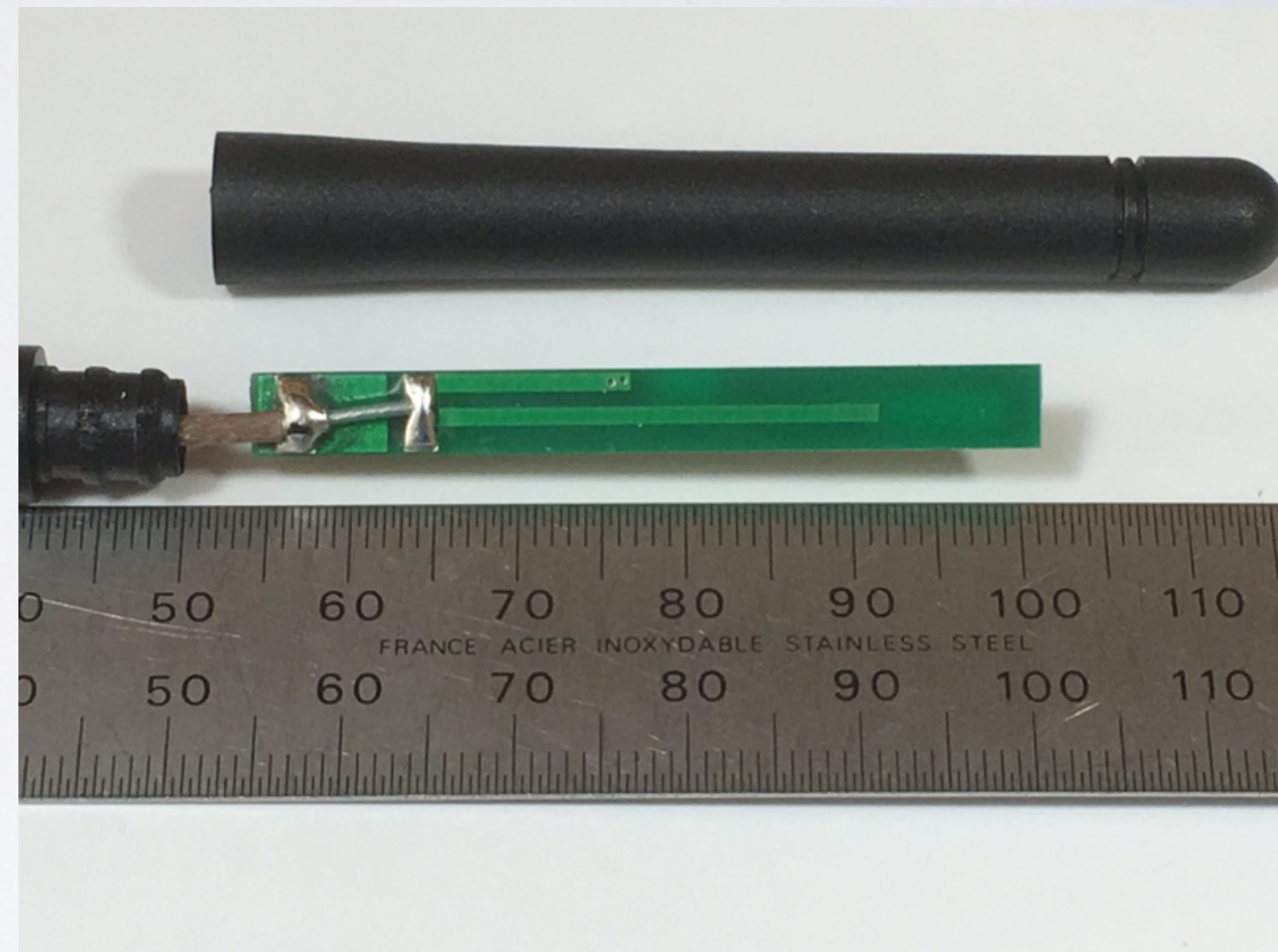
VSWR	Reflection coef. Γ / S I I	Reflected Power (dB)	Reflected Power (%)
1.0	0.0000	Infinity	0.0
1.1	0.0476	26.44	0.2
1.2	0.0909	20.83	0.8
1.3	0.1304	17.69	1.7
1.4	0.1667	15.56	2.8
1.5	0.2000	13.98	4.0
1.6	0.2308	12.74	5.3
1.7	0.2593	11.73	6.7
1.8	0.2857	10.88	8.2
1.9	0.3103	10.16	9.6
2.0	0.3333	9.542	11.1
2.1	0.3548	8.999	12.6
2.2	0.3750	8.519	14.1
2.3	0.3939	8.091	15.5
2.4	0.4118	7.707	17.0
2.5	0.4286	7.360	18.4
2.6	0.4444	7.044	19.8

Excellent

Good

Bad

ANTENNA A



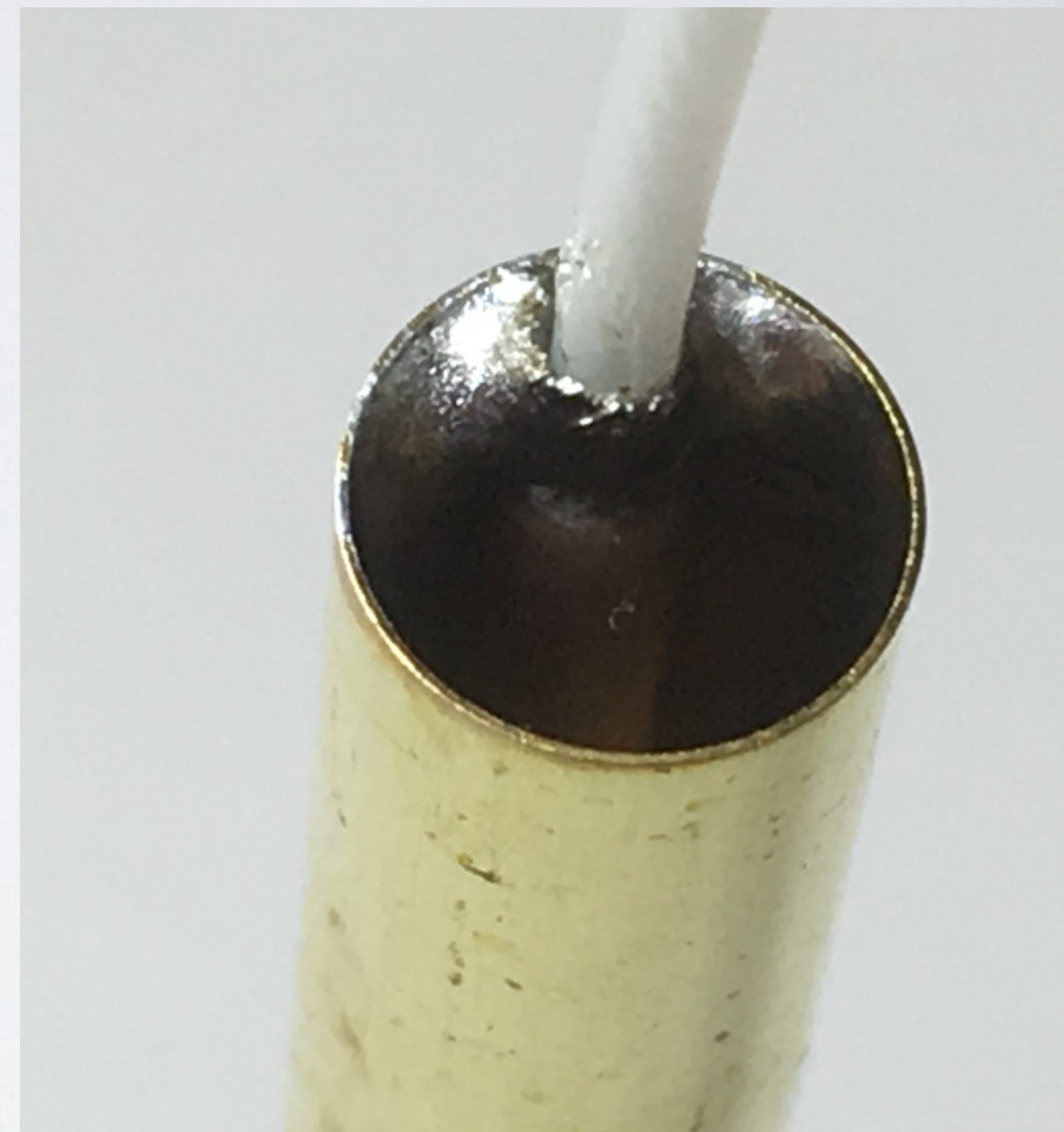
**Antenna A: PCB antenna
Not well tuned.**

ANTENNA B



Antenna B: Sleeve dipole antenna

ANTENNA C



Antenna C: Sleeve dipole antenna

ANTENNA TEST RESULTS

	VSWR	S11 [dB]	Z [Ω]	Reflected Power [%]
Antenna A	6.8	-2.5	60	56.2
Antenna B	1.9	-10.2	41	9.6
Antenna C	1.3	-17.7	44	1.7

Bad**Good****Excellent**

ANTENNA TEST RESULTS 2

- The logged data can be found at:
https://www.mobilefish.com/download/lora/antenna_test_results.txt
- In total there were 4 nearby gateways which were able to receive my transmitted sensor data, see:
https://drive.google.com/open?id=1G-3jSMVhnN85eZvHkFD_fUdorHN--H4l&usp=sharing

ANTENNA TEST RESULTS 2

Gateway	Distance from end device [km]	Altitude [m]	Antenna A	Antenna B	Antenna C
eui-aa555a0000088013	1.57	42	-	RSSI=-119 SNR=-6.7	RSSI=-121 SNR=-8.0
eui-0ba0000000000001	5.03	20	-	RSSI=-120 SNR=-6.1	RSSI=-118 SNR=-9.1
eui-0000024b0806021d	7.63	6	-	RSSI=-119 SNR=-10.2	-
zeezicht	1.23	10	-	-	RSSI=-111 SNR=-10.1