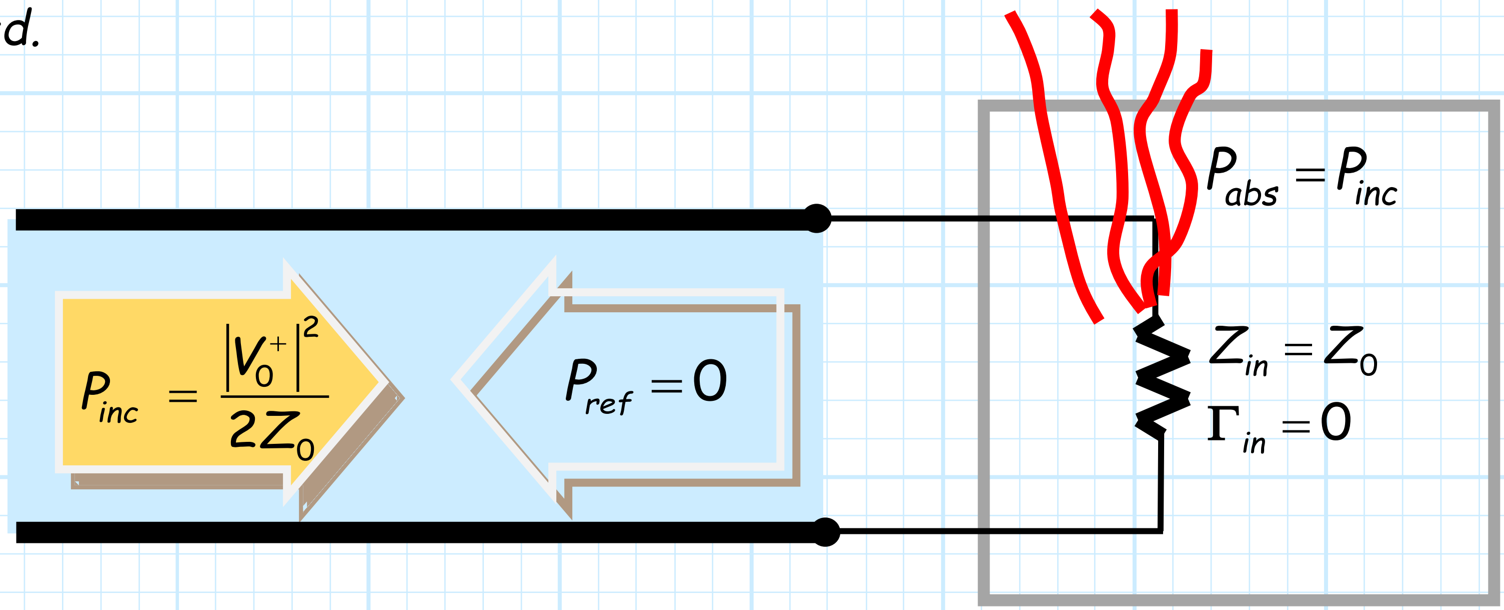
Return Loss and VSWR

Q: ***If*** *the purpose of a transmission line is to transfer* ***energy*** *from some* ***source*** *(the output of some useful device) to some* ***load*** *(the* ***input*** *to some* ***other*** *useful device), then wouldn't an input impedance of Z_0 be* ***ideal****.*

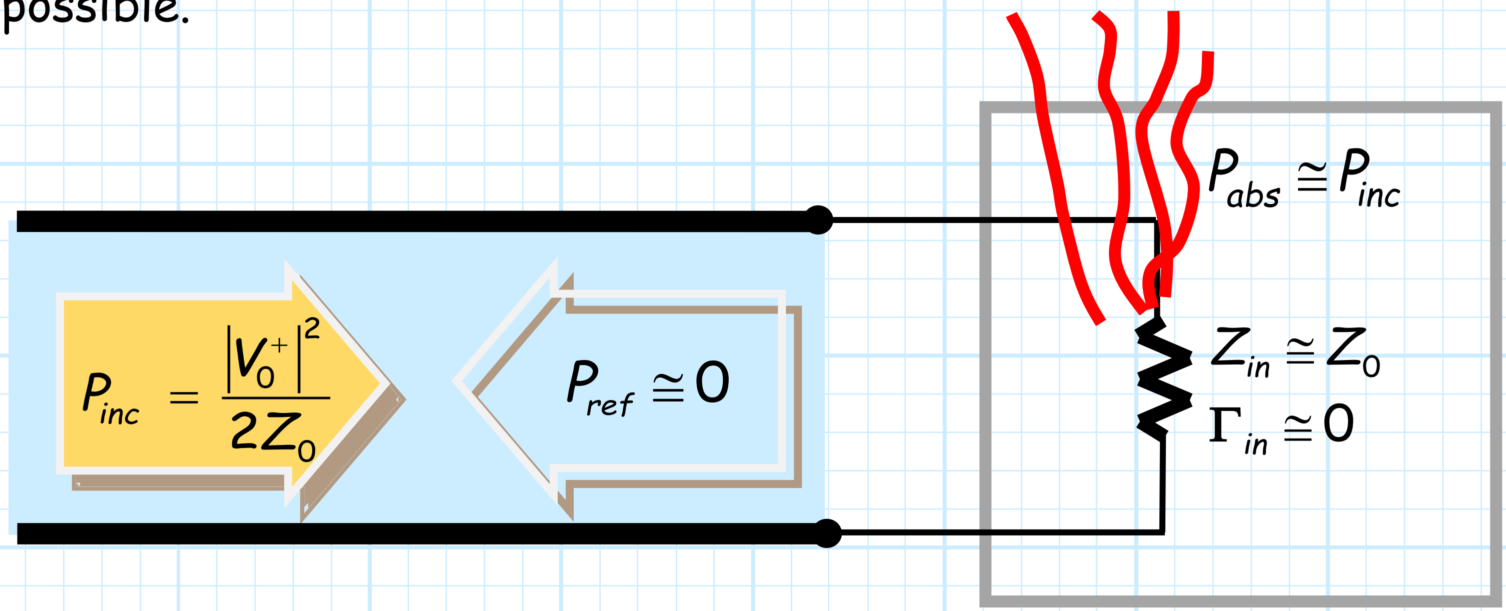
After all, ***no*** *energy is reflected—****all*** *incident energy is* ***absorbed*** *by the load.*



A: **If** connected entirely to other "**matched**" **devices**, it would be!

Close, but not exactly

Thus, microwave component vendors often try very hard to make the **input impedance** of their useful devices as **close** to Z_0 ($Z_0 = 50\Omega$, say) as possible.



But the value:

$$Z_{in} = 50.0000000000000000000000...$$

is **really hard** to come by!

It's not like they're lying (usually)

Q: *So do vendors tell us what Z_{in} **really** is?*

A: Not usually!

Remember, input **impedance**—as well as its **reflection coefficient** Γ_{in}—is a **complex** value.

Therefore microwave engineers often use **real-valued** measures to indicate how **"matched"** a given **load** (e.g., the input impedance of some useful device) really is!

Two of the most prevalent **real-valued** measures are:

1. **return loss**, and

2. **VSWR**.

Return Loss

The **ratio** of the **incident power** to the **reflected power** is known as **return loss**.

Typically, return loss is expressed in **decibels**:

$$\boxed{R.L. = 10\log_{10}\left[\frac{P_{inc}}{P_{ref}}\right] = -10\log_{10}\left|\Gamma_{in}\right|^2}$$

Where:

$$\Gamma_{in} = \frac{Z_{in} - Z_0}{Z_{in} + Z_0}.$$

Return Loss examples

For **example**, if the return loss is **10*dB***, then:

A. **10%** of the incident power is **reflected**, so…

B. the remaining **90%** is **absorbed**, thus…

C. we "**lose**" **10%** of the incident power.

Likewise, **if** the return loss is **30*dB***, then:

A. **0.1%** of the incident power is **reflected**, so…

B. the remaining **99.9%** is **absorbed**, thus…

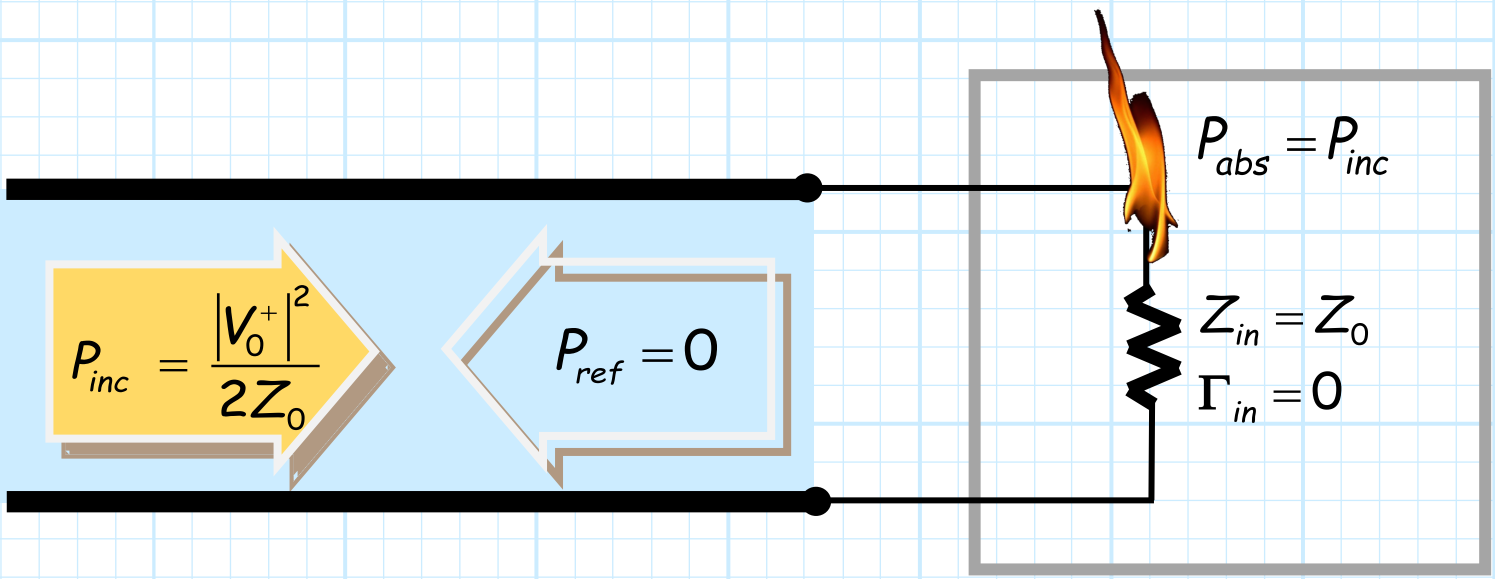
C. we "**lose**" **0.1%** of the incident power.

Thus, a **larger** numeric value for return loss **actually** indicates **less** lost power!

More return loss is actually better

An **ideal** return loss thus would be ∞ *dB*—the input is a **matched load**:

$$R.L. = -10\log_{10}\left|\Gamma_{in}\right|^2 = -10\log_{10}\left|0\right|^2 = \infty$$

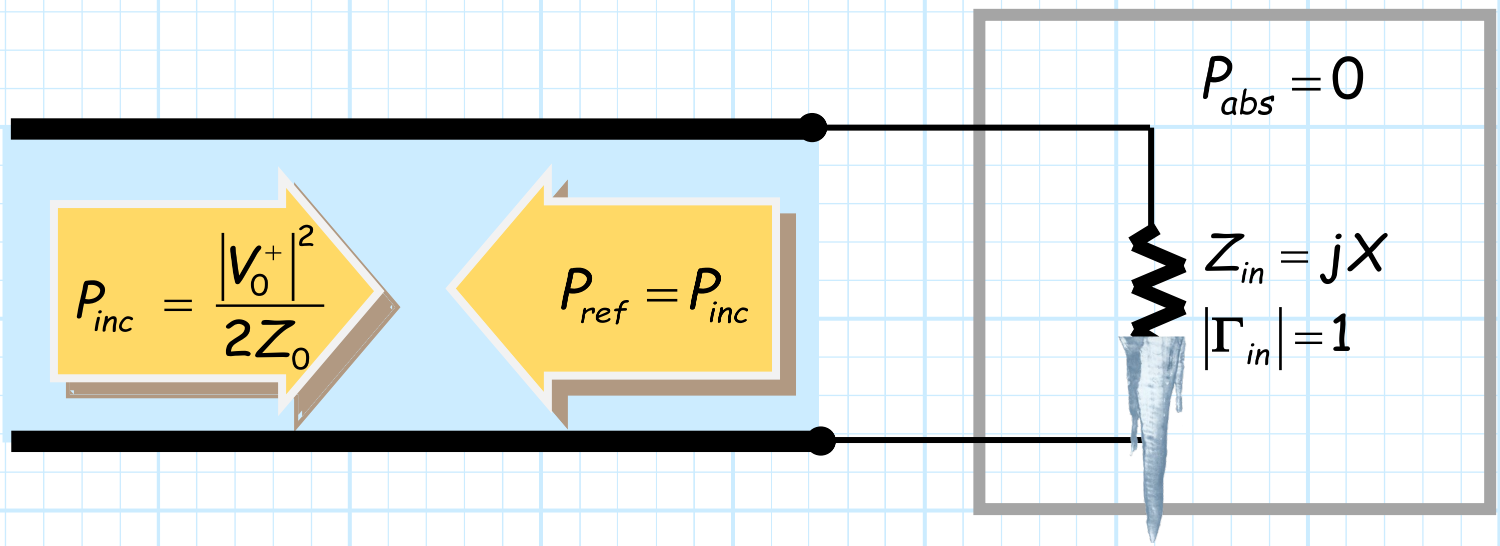


Zero return loss is the worst

The **worst case** is when **no** power is absorbed—all the incident power is **reflected**.

For this (worst) case, the return loss of is **zero**!

$$R.L. = -10\log_{10}|\Gamma_{in}|^2 = -10\log_{10}|1|^2 = 0$$



VSWR

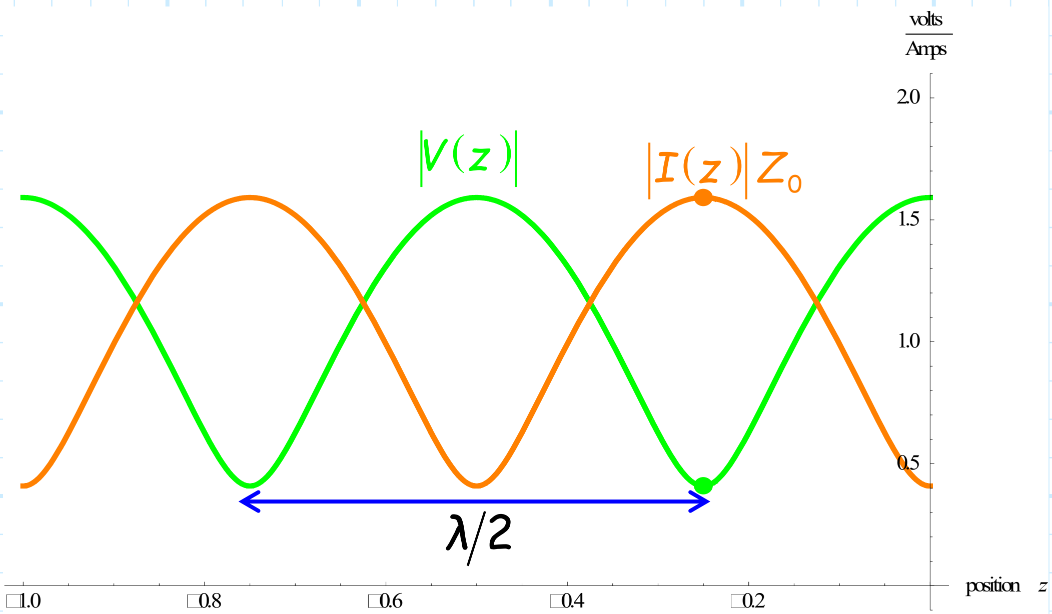
Consider again the **voltage** along a transmission line attached to a port of **some useful device** with impedance Z_{in} (where $z_L = 0$):

$$V(z) = V_0^+\left[e^{-j\beta z} + \Gamma_{in}\, e^{+j\beta z}\right]$$

Now let's look at the **magnitude** only:

$$|V(z)| = |V_0^+|\,\left|e^{-j\beta z} + \Gamma_{in}\, e^{+j\beta z}\right| = |V_0^+|\,\left|1 + \Gamma_{in}\, e^{+j2\beta z}\right|$$

As this result shows—and as **you** already know—the magnitude is **not constant** with respect to position z.



Definition

It can be shown that the **largest** and **smallest** values of this magnitude are:

$$|V(z)|_{max} = |V_0^+|\left(1 + |\Gamma_{in}|\right) \qquad |V(z)|_{min} = |V_0^+|\left(1 - |\Gamma_{in}|\right)$$

The ratio of $|V(z)|_{max}$ to $|V(z)|_{min}$ is known as the **Voltage Standing Wave Ratio** (VSWR):

$$\boxed{\text{VSWR} \doteq \frac{|V(z)|_{max}}{|V(z)|_{min}} = \frac{1 + |\Gamma_{in}|}{1 - |\Gamma_{in}|} \quad \therefore \quad 1 \leq VSWR \leq \infty}$$

As with **return loss**, VSWR is a real value that is on dependent on the **magnitude** of Γ_{in} (i.e, $|\Gamma_{in}|$) **only** !

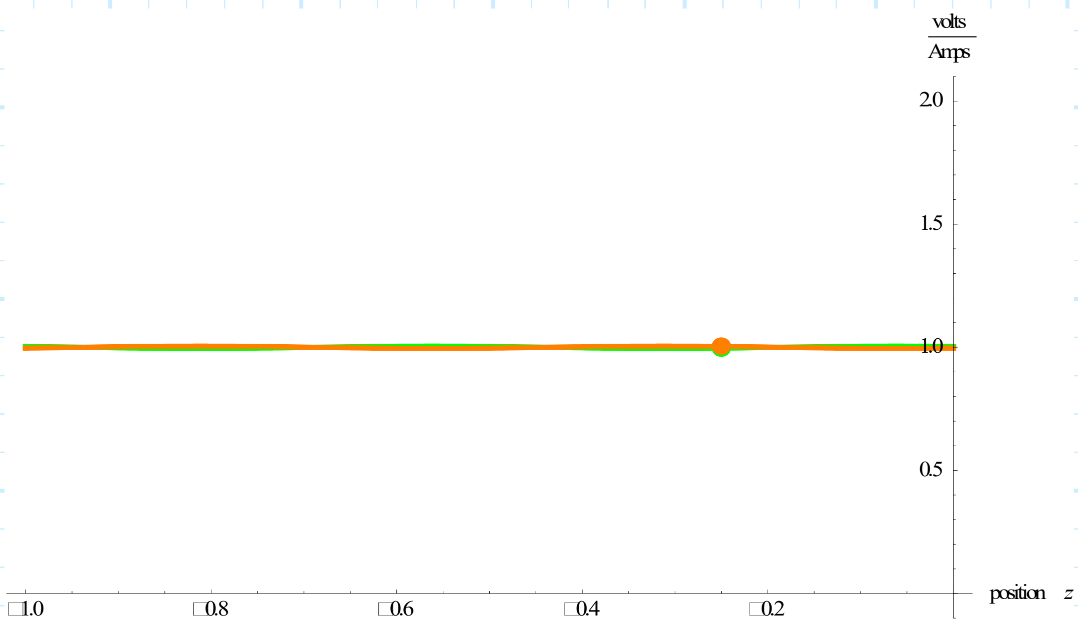
The best VSWR is 1.0

Note for the **ideal** input impedance, where $|\Gamma_{in}| = 0$ (i.e., $Z_{in} = Z_0$), then **VSWR = 1.0** .

We find for this case:

$$|V(z)|_{max} = |V(z)|_{min} = |V_0^+|$$

In other words, the voltage magnitude is a **constant** with respect to position z.



The worst VSWR is infinite

Conversely, for the **worst** input impedance where $|\Gamma_{in}| = 1$, then $VSWR = \infty$.

We find for **this** case:

$$|V(z)|_{min} = 0 \quad \text{and} \quad |V(z)|_{max} = 2\,|V_0^+|$$

Recall for this case the **voltage magnitude** $|V(z)|$ varies **greatly** with respect to position z!