# How much return loss is too much?: Rule of Thumb #12

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This rule of thumb enables us to estimate the maximum amount of return loss allowed for a component like a connector or package.

**Spoiler summary**: A return loss smaller than -13 dB won't affect the transmitted signal.

**Remember**: before you start using rules of thumb, be sure to read the Rule of Thumb #0: Use rules of thumb wisely.

**Previous**: What is the bandwidth of a high speed serial link signal?: Rule of Thumb #11

S-parameters are confusing and mysterious to 99% of the engineers who use them – they are a black box that most engineers are intimidated about opening. This means that when they are used to define a specification, sometimes the folks who write the specs don't understand enough about S-parameters to make intelligent decisions. This rule of thumb is a good sanity check on any specification for return loss.

The S-parameters for an interconnect describe how sine waves scatter off the interconnect. The reflected term, S11, is the ratio of the sine wave that reflects from the front of the interconnect, compared to the sine wave incident to that port. The transmitted S-parameter, S21, is the ratio of the sine wave at the receiver port 2, compared to the sine wave incident on port 1.

If the interconnect has very little loss, there is a connection between the S11 and the S21 terms. After all, if you send energy in, you have to get it all out. The energy in a sine wave is related to the square of the amplitude, so conservation of energy is:

$$1 = S_{11}^2 + S_{21}^2 \quad \text{and} \quad S_{21} = \sqrt{1 - S_{11}^2}$$

If we know S11, in the absence of losses in the interconnect, we also know S21. This relationship is for the magnitudes. For example, if the reflection coefficient, S11 is 10%, which sounds like a lot, the transmitted signal will be 99.5% . This is startling. 10% is a lot of reflected amplitude yet its impact on the transmitted signal is minuscule.

We usually describe each S-parameter in dB. As the reflection in dB increases, at what point will the transmitted signal, S21, be "significantly" affected? Suppose we arbitrarily say we would care about a drop in S21 of -0.5 dB. How much S11 do we need to have to cause as much as -0.5 dB drop in S21?

This is easy to estimate. We pick a value for S11 in dB, convert it to magnitude, calculate the S21 as a magnitude and convert this S21 back into dB. **Figure 1** shows the relationship between the reflected S11 and the transmitted S21.

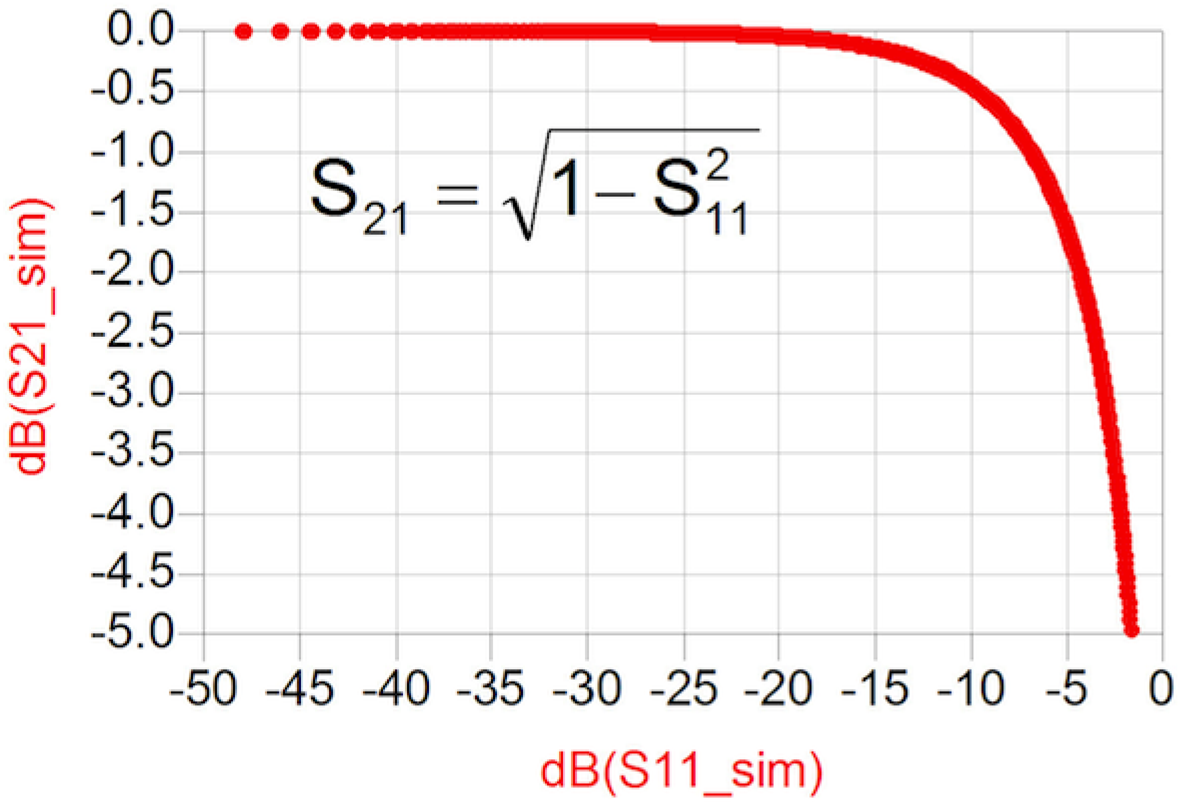


**Figure 1** Relationship between S11 and S21 for a lossless interconnect

When S11 is -40 dB, the impact on S21 is so small that it does not even move the line off the 0 dB peg. -30 dB of S11 has no impact on S21. Even -20 dB of S11 has no impact on S21, in dB. In fact we have to have as much as -15 dB to just barely see the impact on S21, on this scale.

How much S21 is too much? If we pick -0.5 dB as a significant amount, then we see that we could have as much as -10 dB of S11 before its impact on S21 is -0.5 dB. This is very surprising.

It is astonishing that there could be as much as -10 dB S11, which is 30% reflected signal, before we see -0.5 dB in the transmitted signal, S21. Depending on where you want to draw your limit of how much impact on S21 is too much, the threshold of allowable S11 is around -10 dB to -15 dB. A good compromise is -13 dB.

This is the origin of the rule of thumb, that the maximum acceptable value of S11 for an interconnect structure is about -13 dB:

> *If S11 is smaller than -13 dB, we will not see the impact from these reflections on the transmitted signal. However, if S11 is larger than -13 dB, then expect to see some impact on S21.*

For example, a connector has -20 dB of S11. Is this significant? No, it is not. This connector will look transparent in the system.

Now you try it:

1. The return loss of a via is calculated as -25 dB. Is this good or bad?
2. A short transmission line section has a peak return loss of -15 dB. What impedance difference between the line and the ports does this correspond to?

Next rule of thumb: RoT #13: The quarter wave stub frequency of a via stub.