SAS-2 Transmitter/Receiver S-Parameter Measurement (07-012r0)

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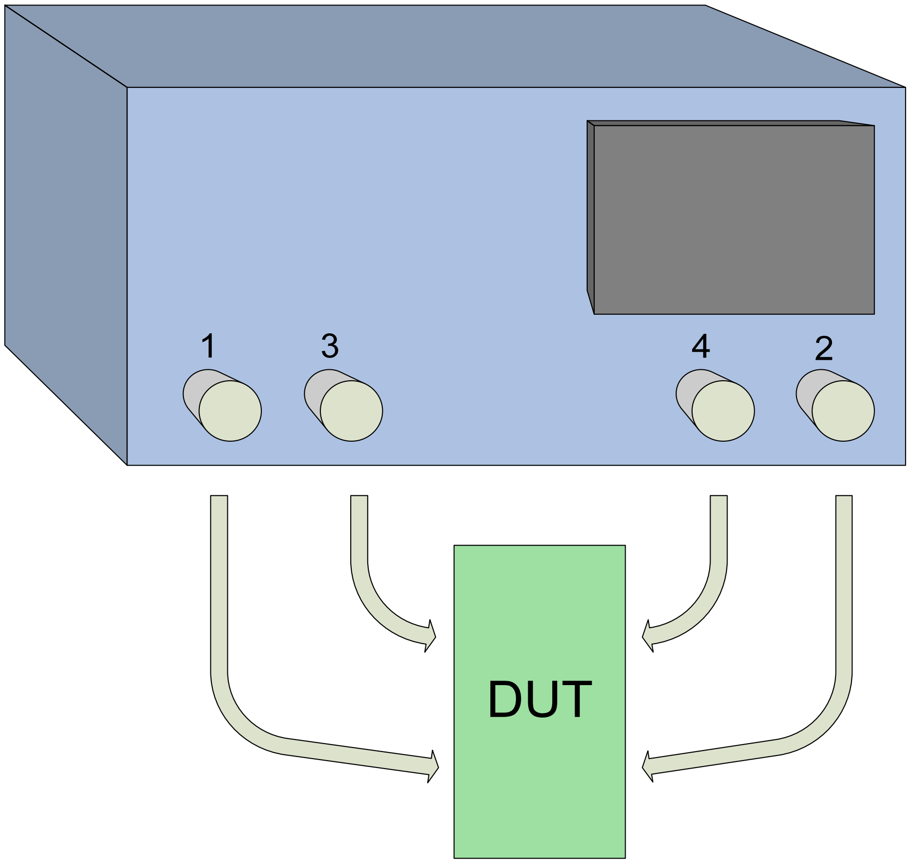
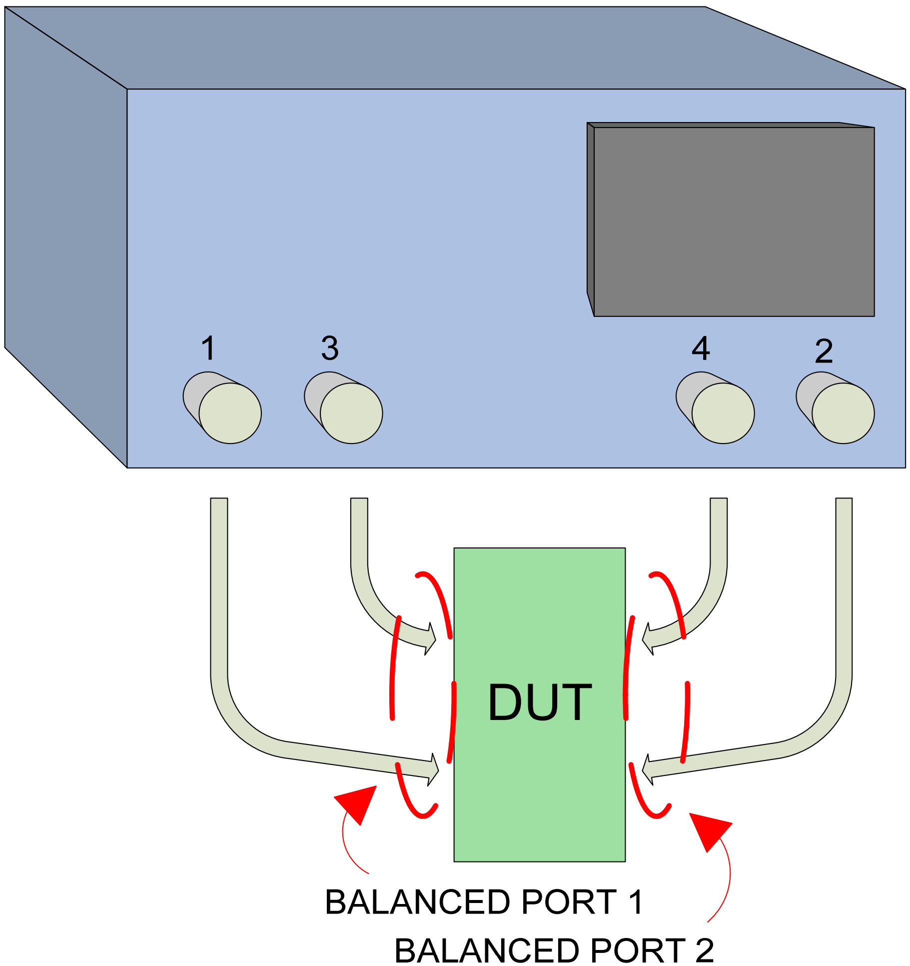
S-Parameter Measurement



S11	**S12**	**S13**	**S14**
S21	**S22**	**S23**	**S24**
S31	**S32**	**S33**	**S34**
S41	**S42**	**S43**	**S44**

Four Port S-Parameter Table

Balanced S-Parameter Measurement



Sdd11	Sdd12	Sdc11	Sdc12
Sdd21	Sdd22	Sdc21	Sdc22
Scd11	Scd12	Scc11	Scc12
Scd21	Scd22	Scc21	Scc22

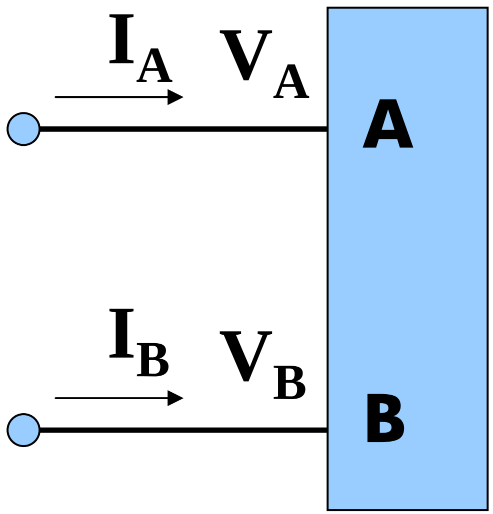
Two Port Balanced (differential)
S-Parameter Table

S-Parameter Terminology

- For unbalanced terms the form is,
  - $S_{\text{<measured port><injected port>}}$
  - For example, S_{32} is the response measured at port 3 from the signal injected into port 2
- For balanced terms the form is,
  - $S_{\text{<mode of measured port><mode of injected port> <measured port><injected port>}}$
  - For example, S_{dc12} is the differential response measured at ports 1/3 from a common mode signal injected on both ports 2 and 4 (see balanced measurement diagram)
- Correctly interpreting the common mode to differential conversion measurement is difficult. More on that topic later.
- This presentation will focus on the various S_{11} terms

Balanced Port Values

	Differential Mode	Common Mode
Voltage	$V_A - V_B$	$\dfrac{V_A + V_B}{2}$
Current	$\dfrac{I_A - I_B}{2}$	$I_A + I_B$
Impedance	$Z_{DM} = \dfrac{V_{DM}}{I_{DM}}$	$Z_{CM} = \dfrac{V_{CM}}{I_{CM}}$



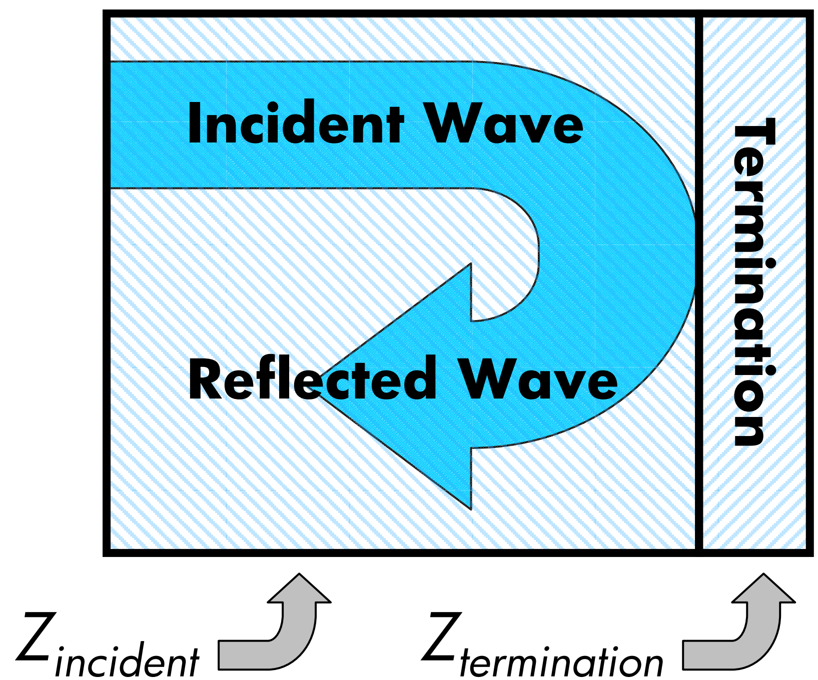
Balanced 1-port

Reflection Coefficient (Γ) and S_{11}

- How do the S_{11} terms correlate to the reflection coefficient?
- The reflection coefficient (Γ) is the ratio of the amplitudes of the reflected wave to the incident wave
- It can be computed from the impedances of the incident media and termination
- The magnitude of Γ is ρ and the S_{11} magnitude is then

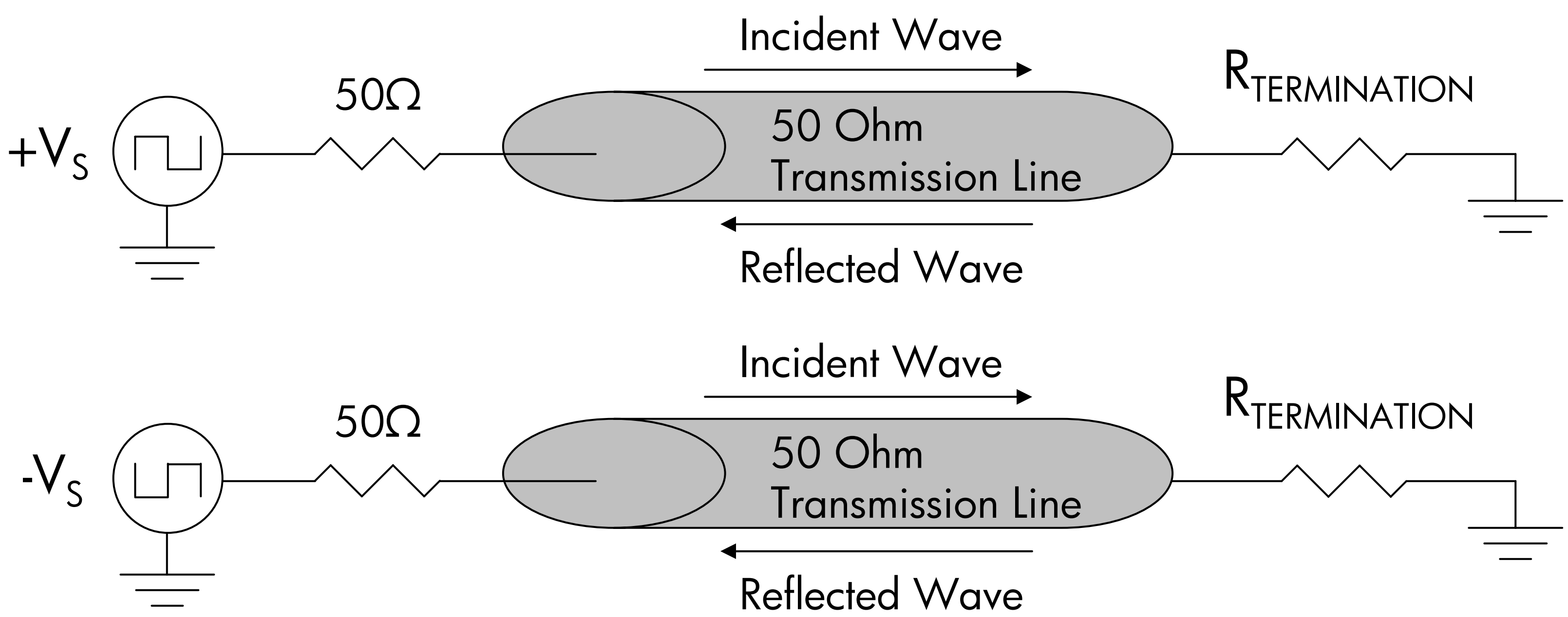
$$S_{11} = 20\log(\rho)$$

$$\Gamma = \frac{V_{reflected}}{V_{incident}} = \frac{Z_t - Z_i}{Z_t + Z_i}$$



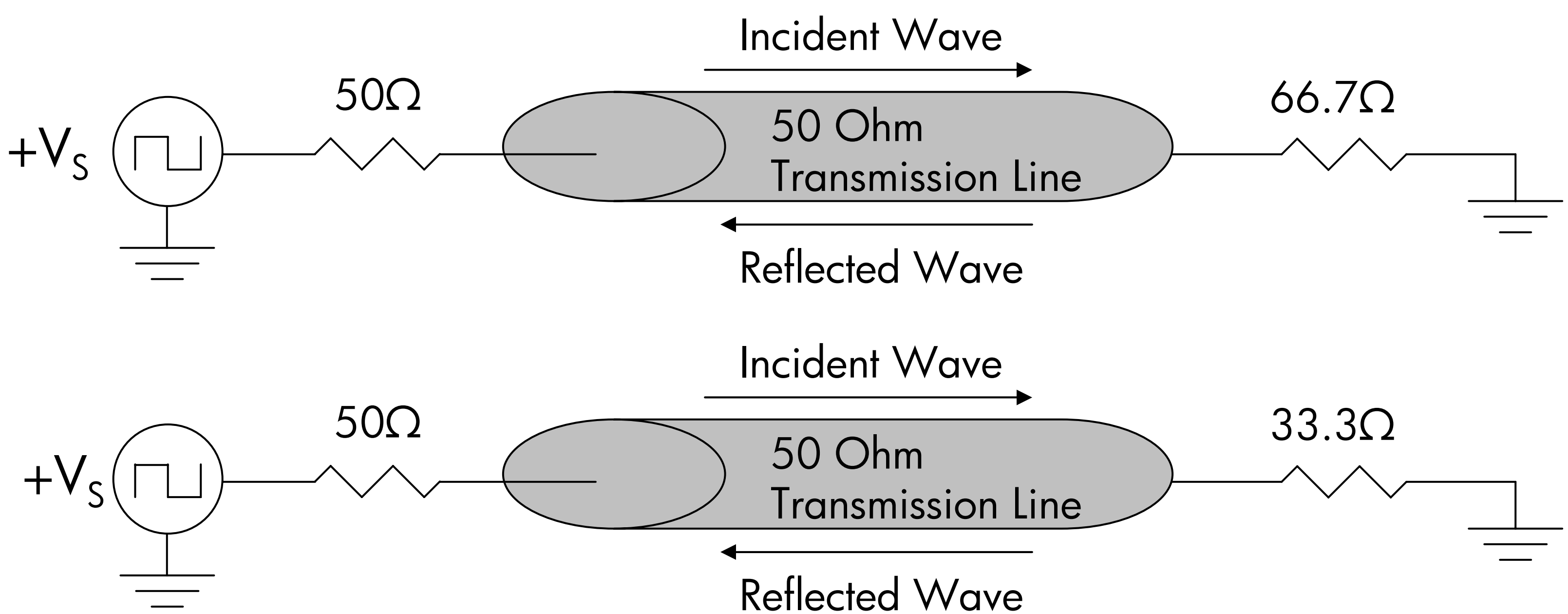
Comparison of ρ and S_{11} Results

- To verify the interpretation of the S_{11} terms is correct, the following circuit was constructed with various termination values
- Both S_{11} and ρ where measured. S_{11} was then verified using the equations presented earlier



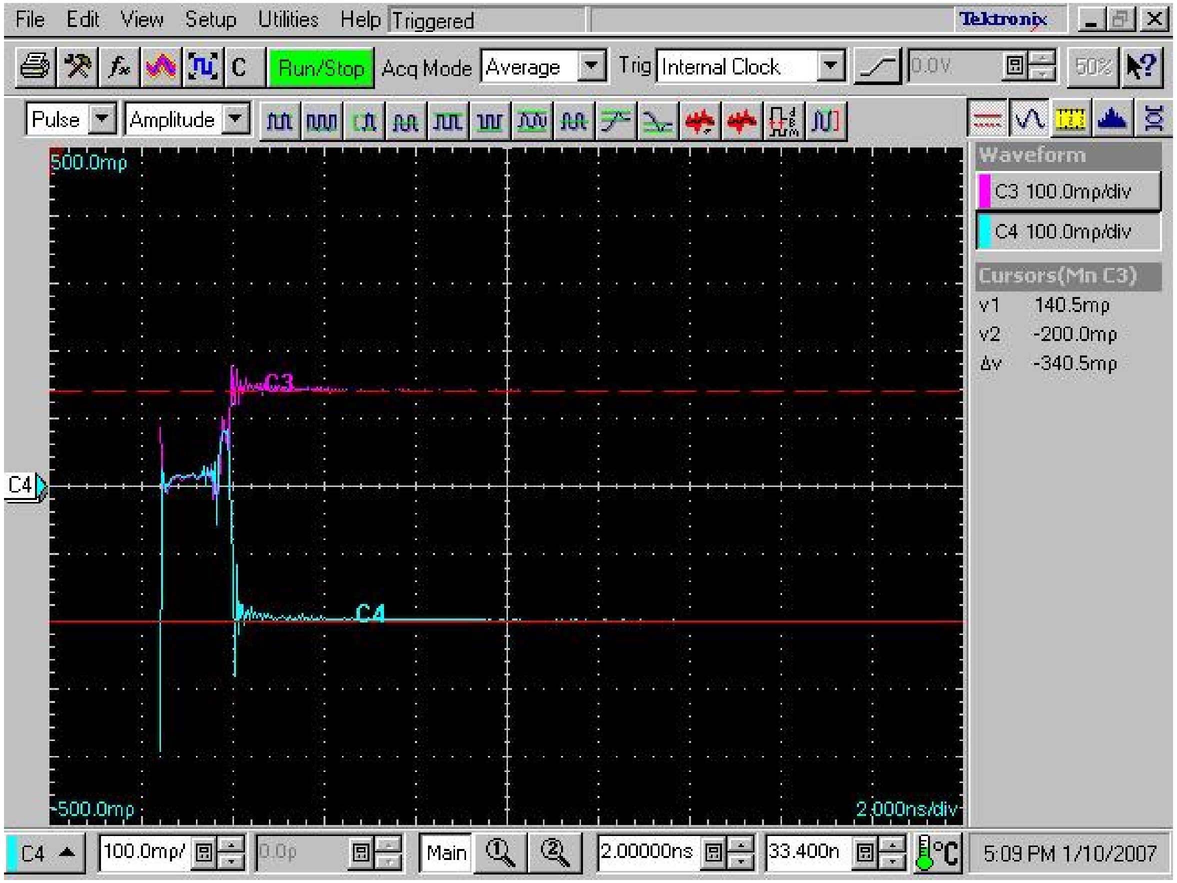
Comparison of ρ and S_{11} Results

- In the following case the differential impedance matches the transmission line at 100Ω but the common mode impedance is 22.2Ω. Since the legs are mismatched a conversion is also introduced. We will introduce a common mode signal and analyze the conversion.



Comparison of ρ and S_{11} Results

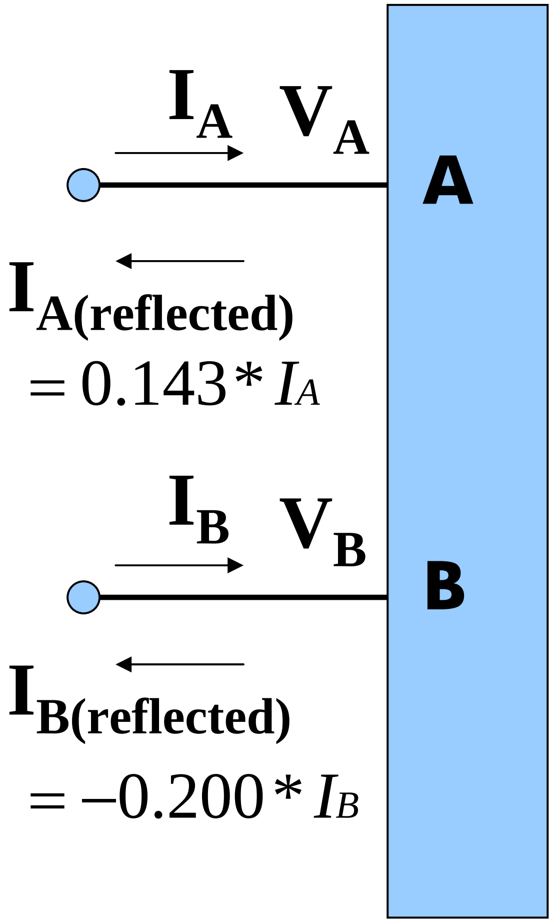
- Calculating the reflection coefficient ρ for the first leg we obtain is 0.143 and -0.200 for the second
- Also note that the results match very closely to the measured values
- For the reflected wave the first leg experiences a positive transitioning signal and the second leg a negative transitioning one



$$\rho = \frac{66.7-50}{66.7+50} = 0.143 \qquad \rho = \frac{33.3-50}{33.3+50} = -0.200$$

Comparison of ρ and S_{11} Results

- The reflected waves can be thought of as a signal injected into the instrumentation by the DUT. The same balanced port equations apply but in the opposite direction
- The reflected waves can be expressed as a ratio of the original signal injected into the termination network
- To determine S_{DC11} for the DUT, we merely need to interpret the reflected currents as differential mode signals



Balanced 1-port

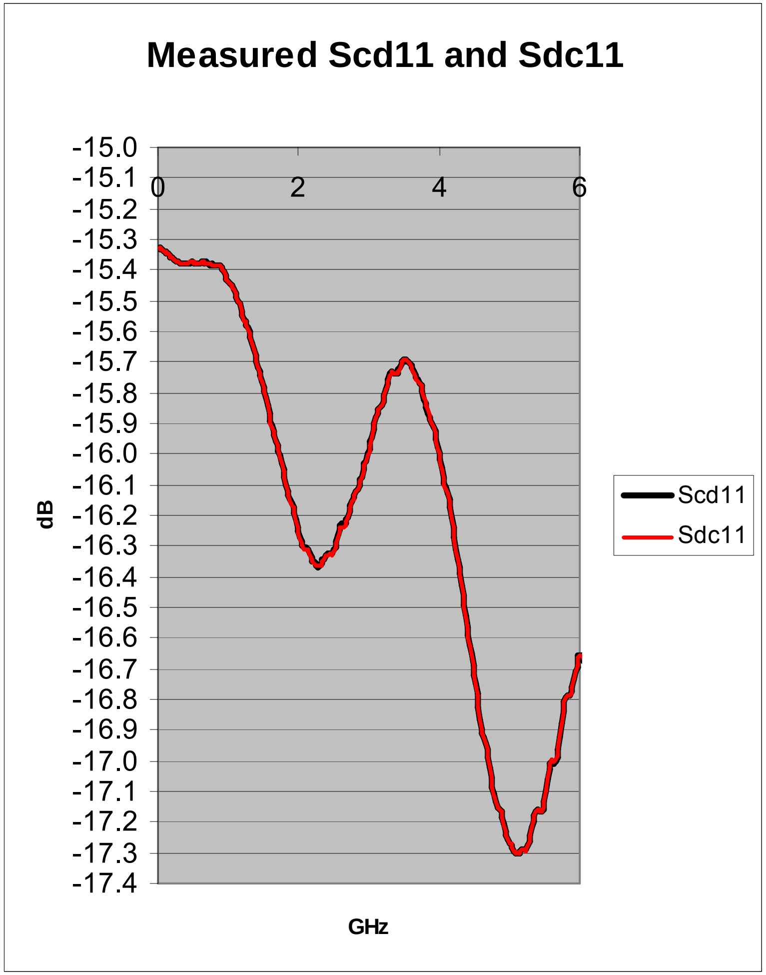
Comparison of ρ and S_{11} Results

- The equation for differential mode currents presented earlier is $(I_A - I_B)/2$. Using the calculated values we obtain:

$$\frac{0.143-(-0.200)}{2}=0.172$$

$$S_{DC11}=20\log(0.172)=-15.3$$

- Below 1 GHz, this value compares well with the actual measurement shown to the right



Reference Material

- Agilent has two application notes with materials used in this presentation. Both are good for further reading on this topic.

1. Characterization of balanced digital components and communication paths
2. Advanced measurements and modeling of differential devices