M-OSRP
Misson - Oriented Seismic Research Program
Solve The Right Problem

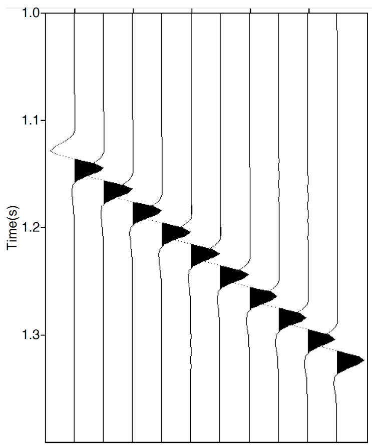
The internal-multiple *elimination* algorithm for all reflectors for 1D earth Part 1: strengths and limitations

Yanglei Zou* and Arthur B. Weglein

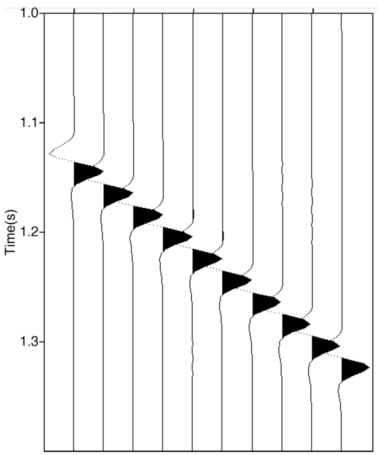
May 29th, 2014
Austin, TX

ISS internal multiple elimination algorithm

Case 1



multiple in data



predicted multiple

Solution

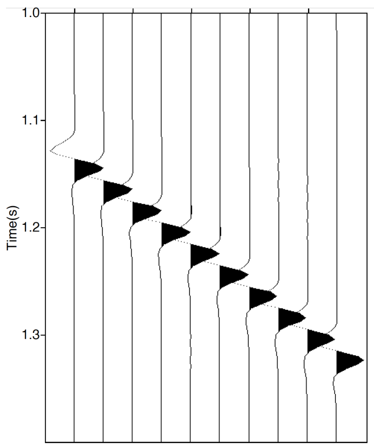
ISS Internal-multiple attenuation algorithm

+ adaptive subtraction

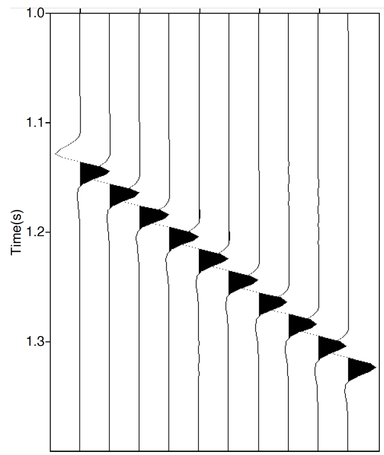
(Figure from Jinlong Yang M-OSRP annual report 2013)

ISS internal multiple elimination algorithm

Case 1

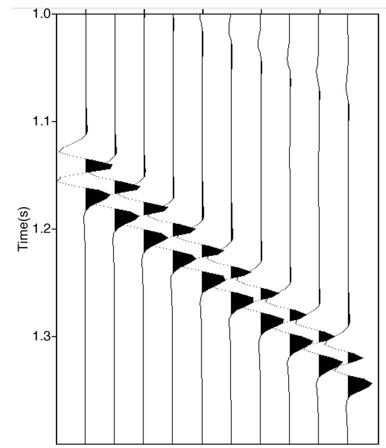


multiple in data

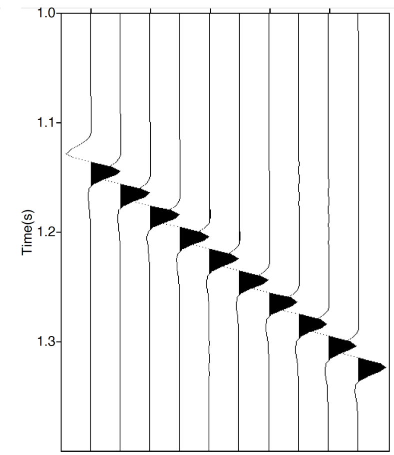


predicted multiple

Case 2



primary and multiple interfering in data



predicted multiple

Solution

ISS Internal-multiple attenuation algorithm

+ adaptive subtraction

Solution

Three-pronged strategy

for internal multiple removal

Weglein (2013)

(Figure from Jinlong Yang M-OSRP annual report 2013)

The three-pronged strategy

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1. **Pre-requisites for on-shore application;**

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2. **Beyond ISS internal multiple attenuation;**

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   a) **Removing artifacts/spurious events**
   b) **Internal multiple elimination**

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1. **Pre-requisites for on-shore application;**
2. **Beyond ISS internal multiple attenuation;**
   a) **Removing artifacts/spurious events**
   b) **Internal multiple elimination**
3. **New adaptive subtraction criteria.**

The three-pronged strategy

1. **Pre-requisites for on-shore application;**

2. **Beyond ISS internal multiple attenuation;**
   a) **Removing artifacts/spurious events**
   b) **Internal multiple elimination**

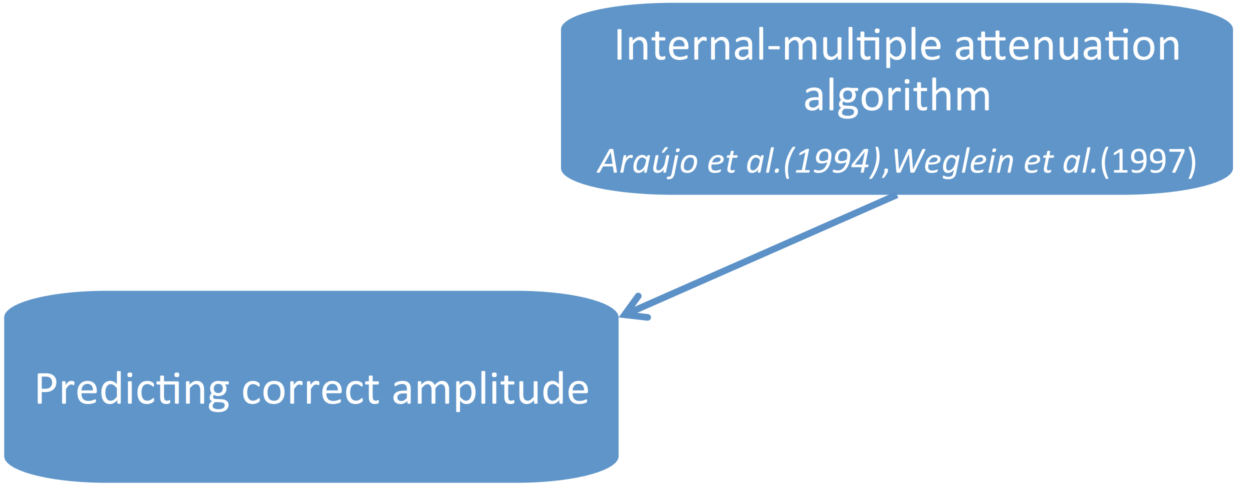
3. **New adaptive subtraction criteria.**

Beyond ISS internal multiple attenuation

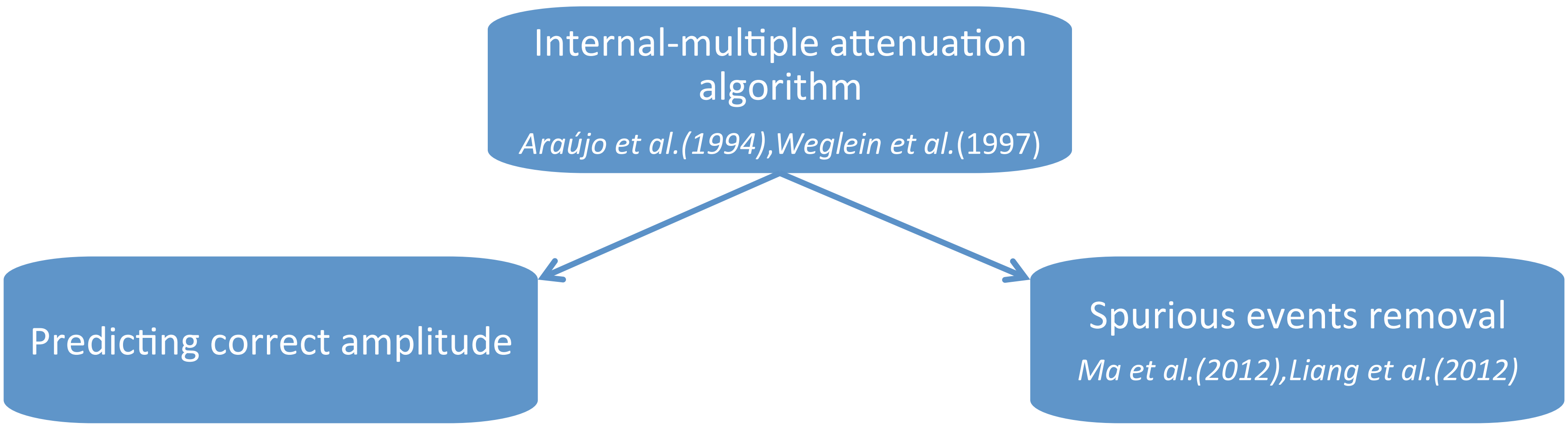
Internal-multiple attenuation algorithm

Araújo et al.(1994),Weglein et al.(1997)

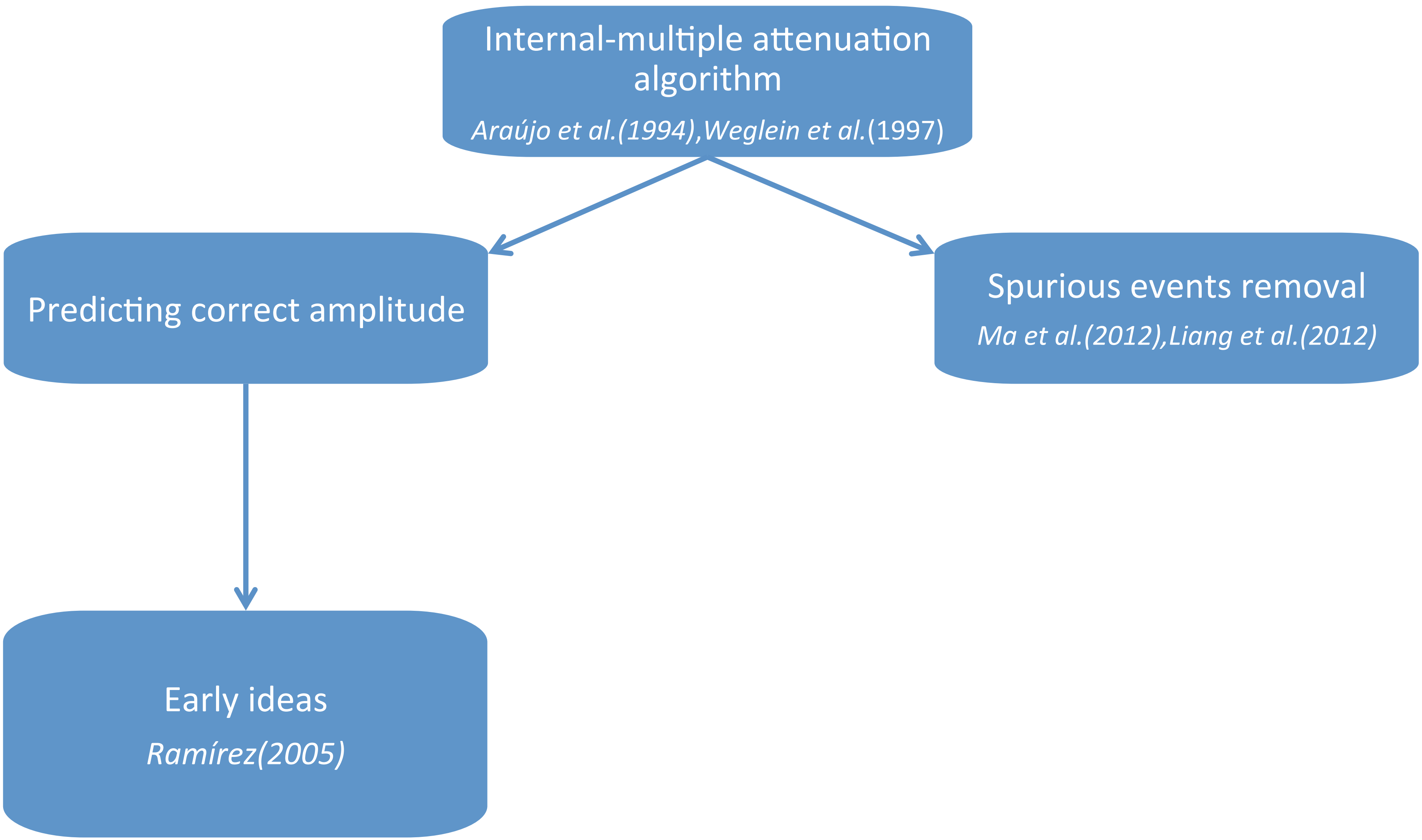
Beyond ISS internal multiple attenuation



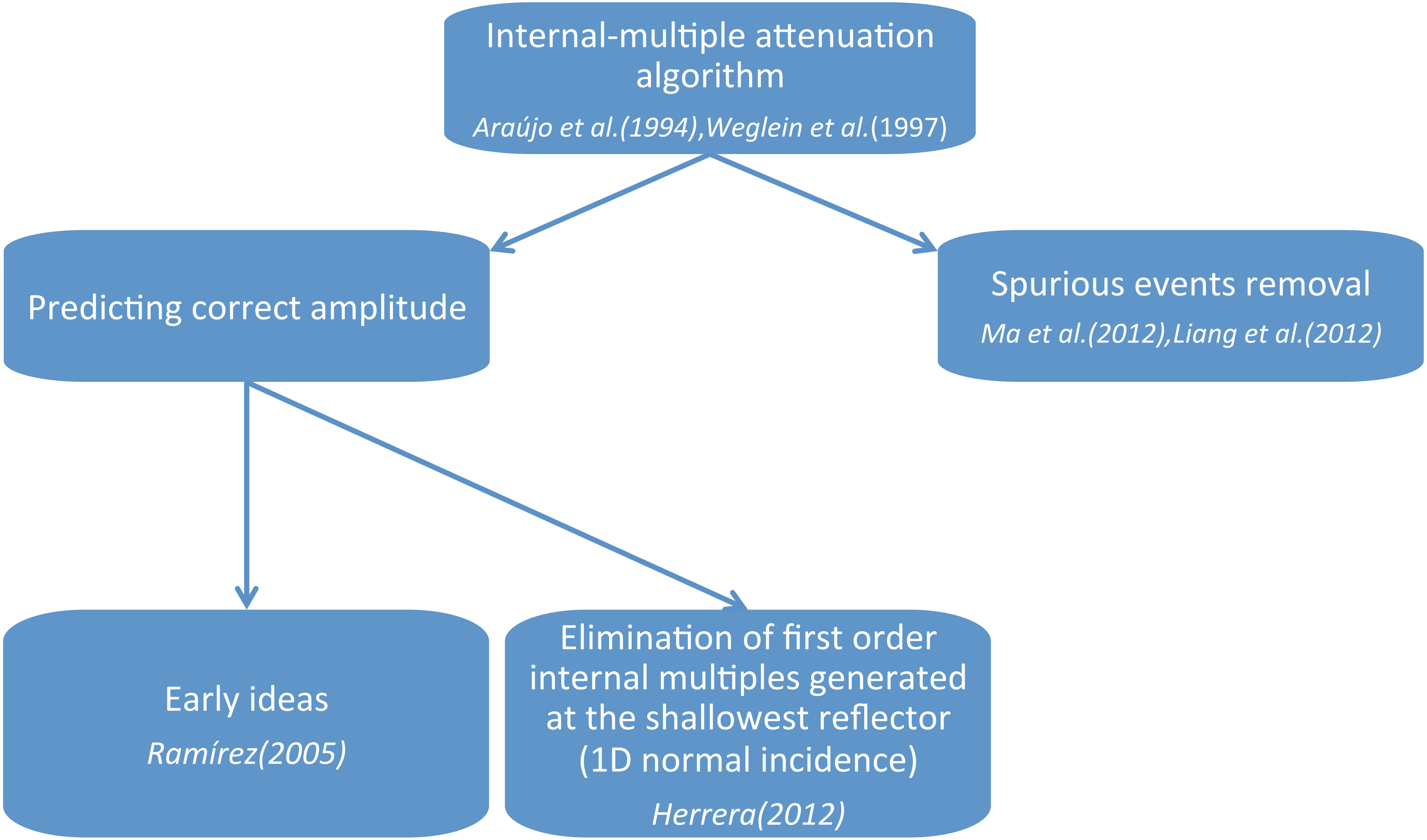
Beyond ISS internal multiple attenuation



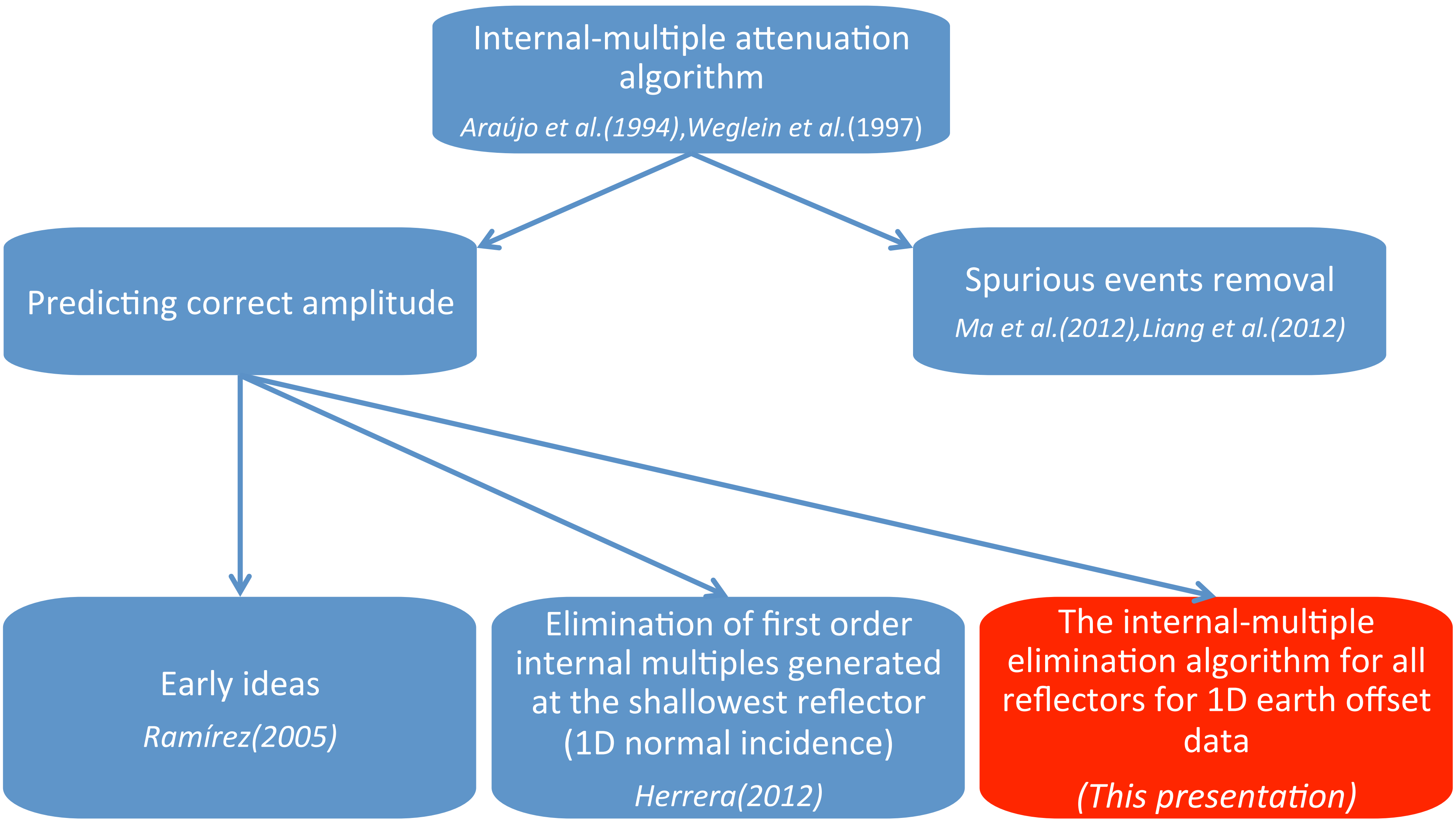
Beyond ISS internal multiple attenuation



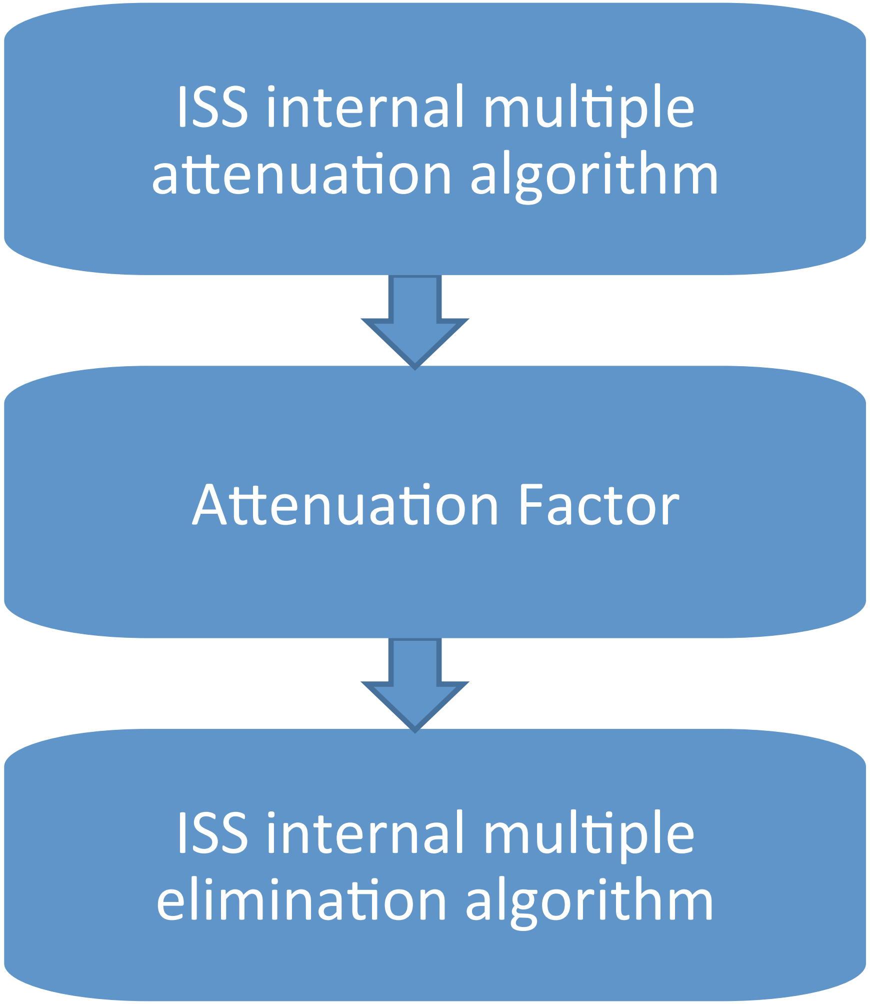
Beyond ISS internal multiple attenuation



Beyond ISS internal multiple attenuation



The structure of this presentation



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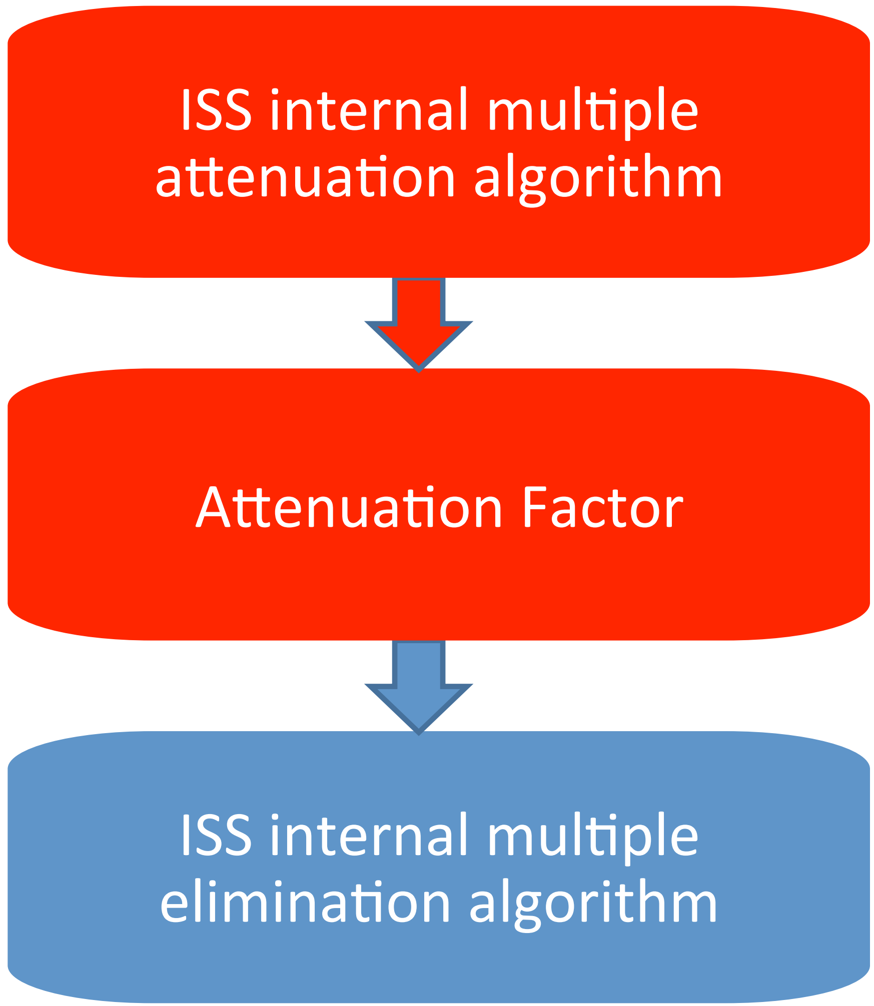


ISS internal multiple attenuation algorithm

The 1D normal incidence version of the internal multiple attenuation algorithm is presented as follows:

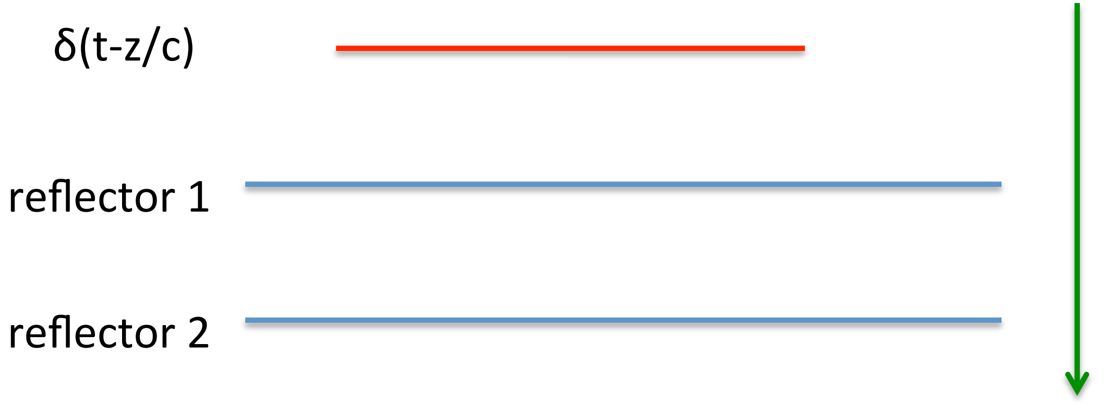
$$b_3^{IM}(k) = \int_{-\infty}^{\infty} dz e^{ikz} b_1(z) \int_{-\infty}^{z-\varepsilon_2} dz' e^{-ikz'} b_1(z') \int_{z'+\varepsilon_1}^{\infty} dz'' e^{ikz''} b_1(z'')$$

ISS internal multiple attenuation algorithm

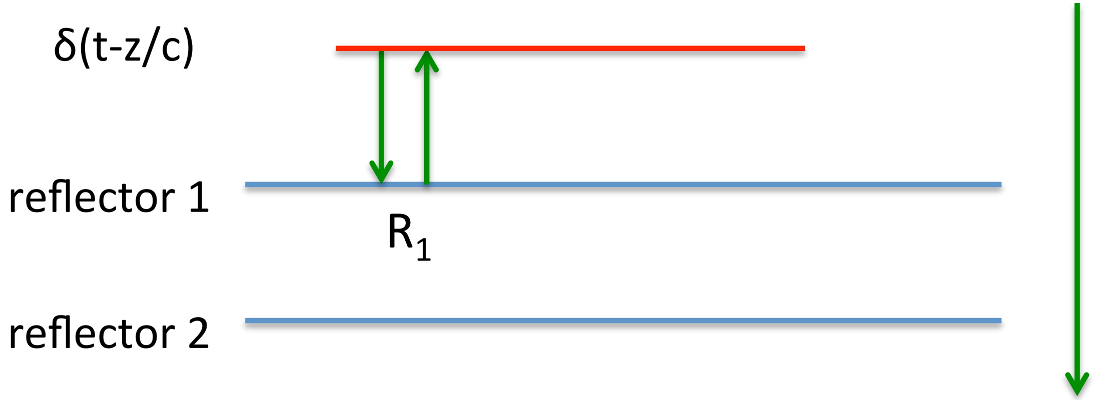
reflector 1

reflector 2

ISS internal multiple attenuation algorithm



ISS internal multiple attenuation algorithm



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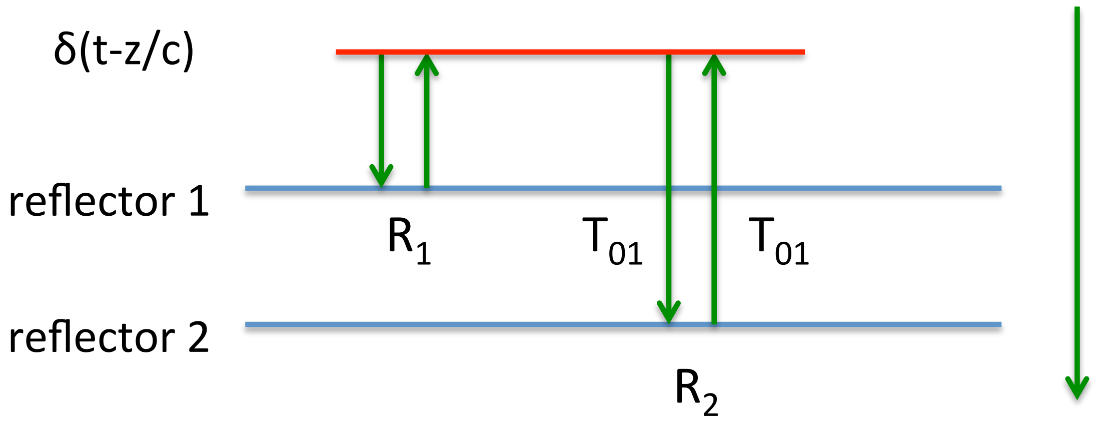

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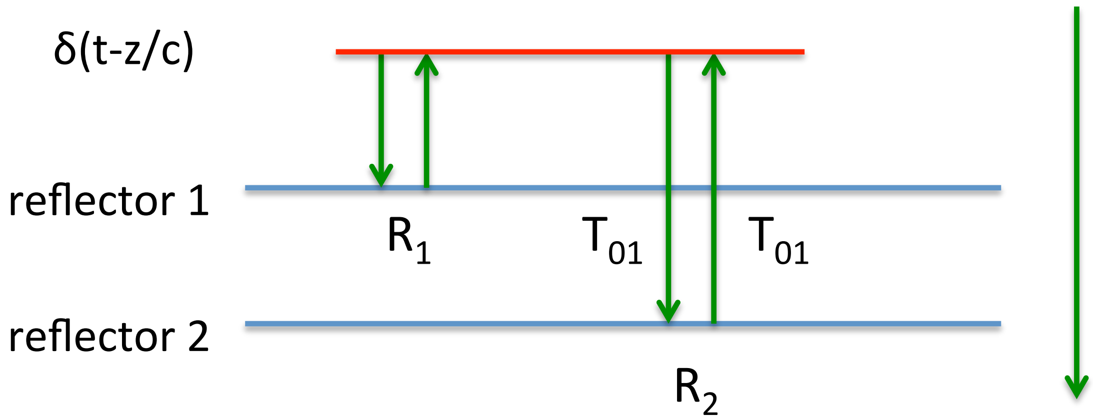
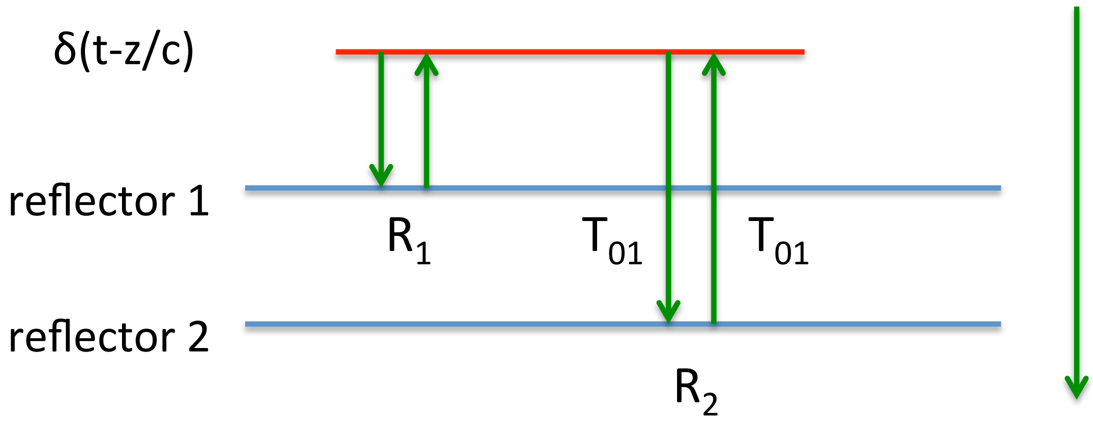


The reflection data caused by an impulsive incident wave δ(t-z/c) is:

$$D(t) = R_1\delta(t - t_1) + T_{01}R_2T_{10}\delta(t - t_2) + \cdots$$

ISS internal multiple attenuation algorithm



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$$D(t) = R_1\delta(t - t_1) + T_{01}R_2T_{10}\delta(t - t_2) + \cdots$$

Make a water speed migration of D(t) with $k_z = \frac{2\omega}{c_0}$
and pseudo-depths: $z_1 = \frac{c_0 t_1}{2}$ $z_2 = \frac{c_0 t_2}{2}$.

$$b_1(z) = R_1\delta(z - z_1) + T_{01}R_2T_{10}\delta(z - z_2) + \cdots$$

ISS internal multiple attenuation algorithm

The ISS internal-multiple attenuation algorithm prediction is:

$$b_3(t) = R_1 R_2^2 T_{01}^2 T_{10}^2 \delta(t - (2t_2 - t_1))$$

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The actual first order internal multiple is:

$$-R_1 R_2^2 T_{01} T_{10} \delta(t - (2t_2 - t_1))$$

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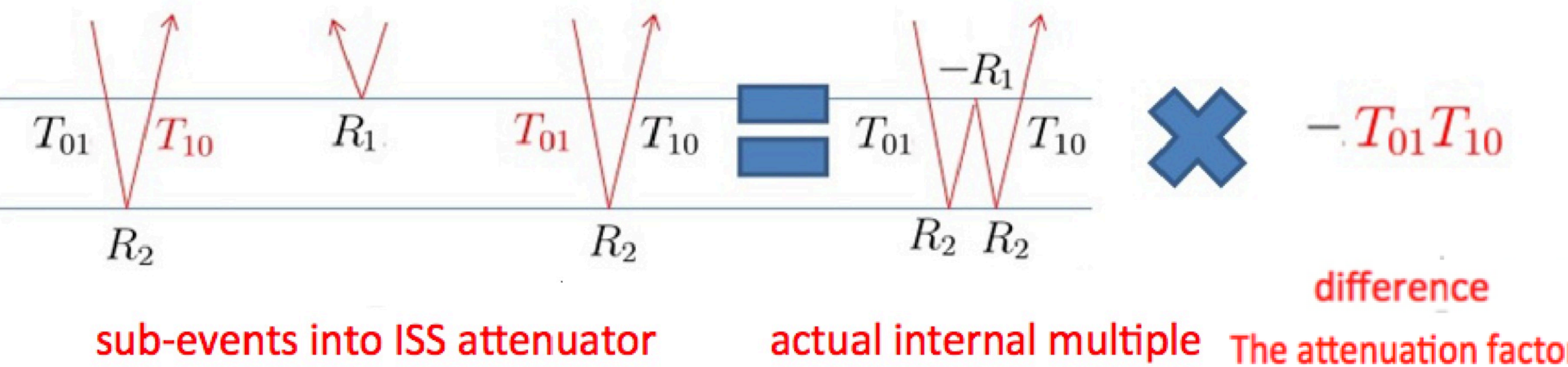
The time prediction is precise, and the amplitude of the prediction has an extra power of $\mathbf{T_{01}T_{10}}$ which is called the **attenuation factor.** This factor is first noted by Weglein and Matson (1998)

The attenuation factor (1D normal incidence)



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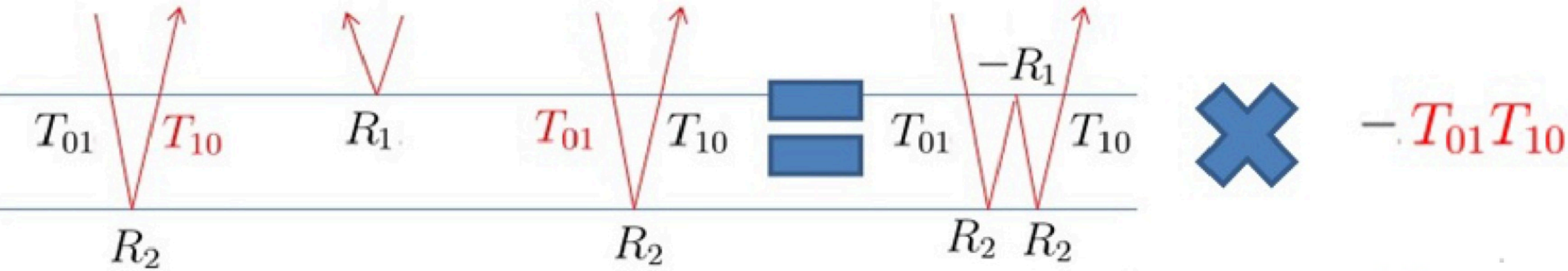
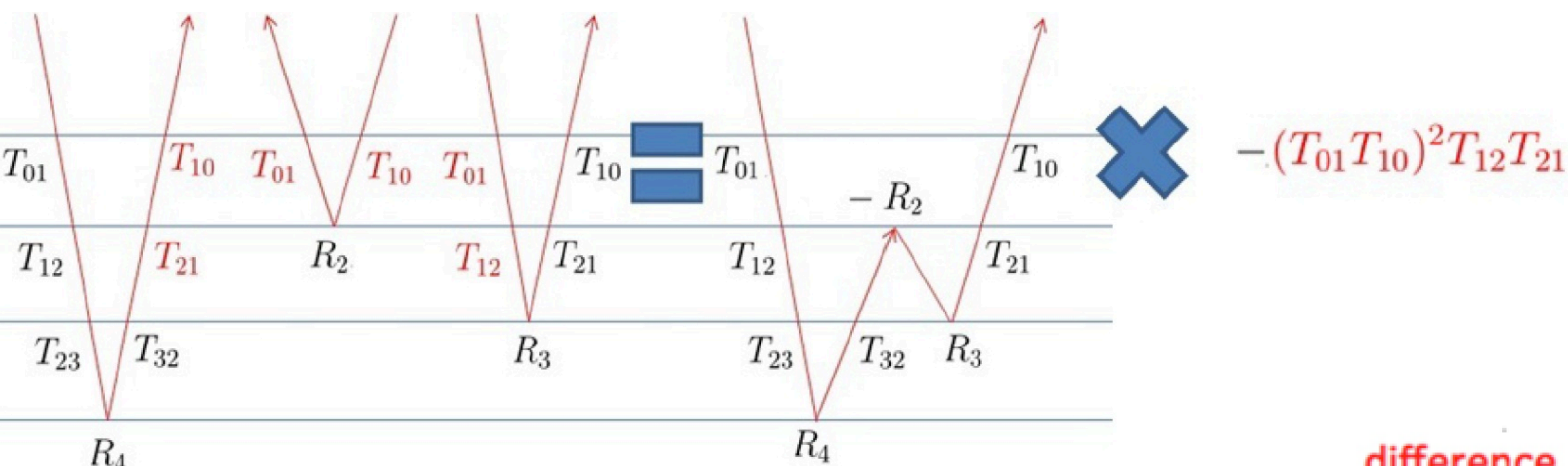


sub-events into ISS attenuator — actual internal multiple — difference — The attenuation factor



sub-events into ISS attenuator — actual internal multiple — difference — The attenuation factor

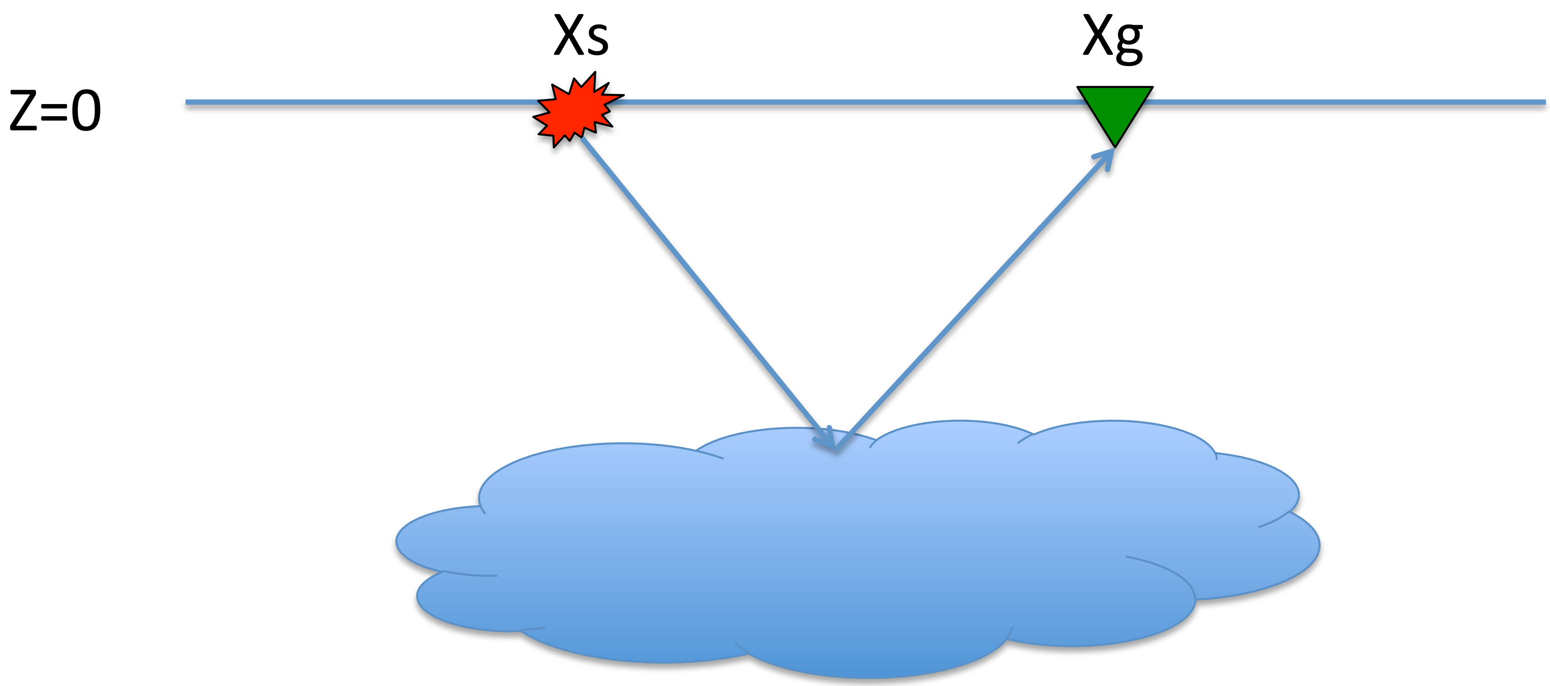
The attenuation factor (1D normal incidence)

A generalization of the **attenuation factor(AF)** is:
(1D normal incidence)

$$AF_j = \begin{cases} T_{0,1}T_{1,0} & (j=1) \\ \prod_{i=1}^{N-1}(T_{i-1,i}^2 T_{i,i-1}^2)T_{j,j-1}T_{j-1,j} & (1<j<J) \end{cases}$$

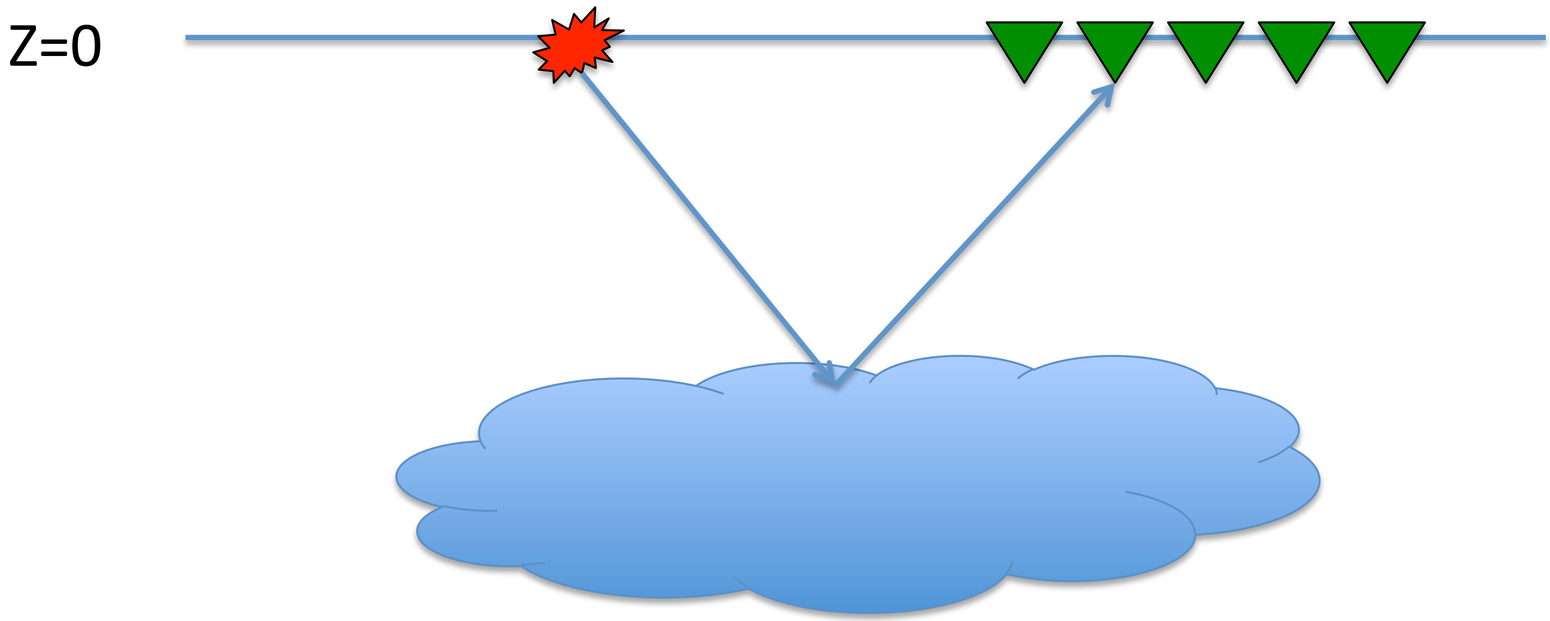
AF_j is the attenuation factor for first order internal multiples with a downward reflection at the j^{th} reflector.

The attenuation factor (1D earth offset data)



$$D(x_s, x_g, t)$$

The attenuation factor (1D earth offset data)



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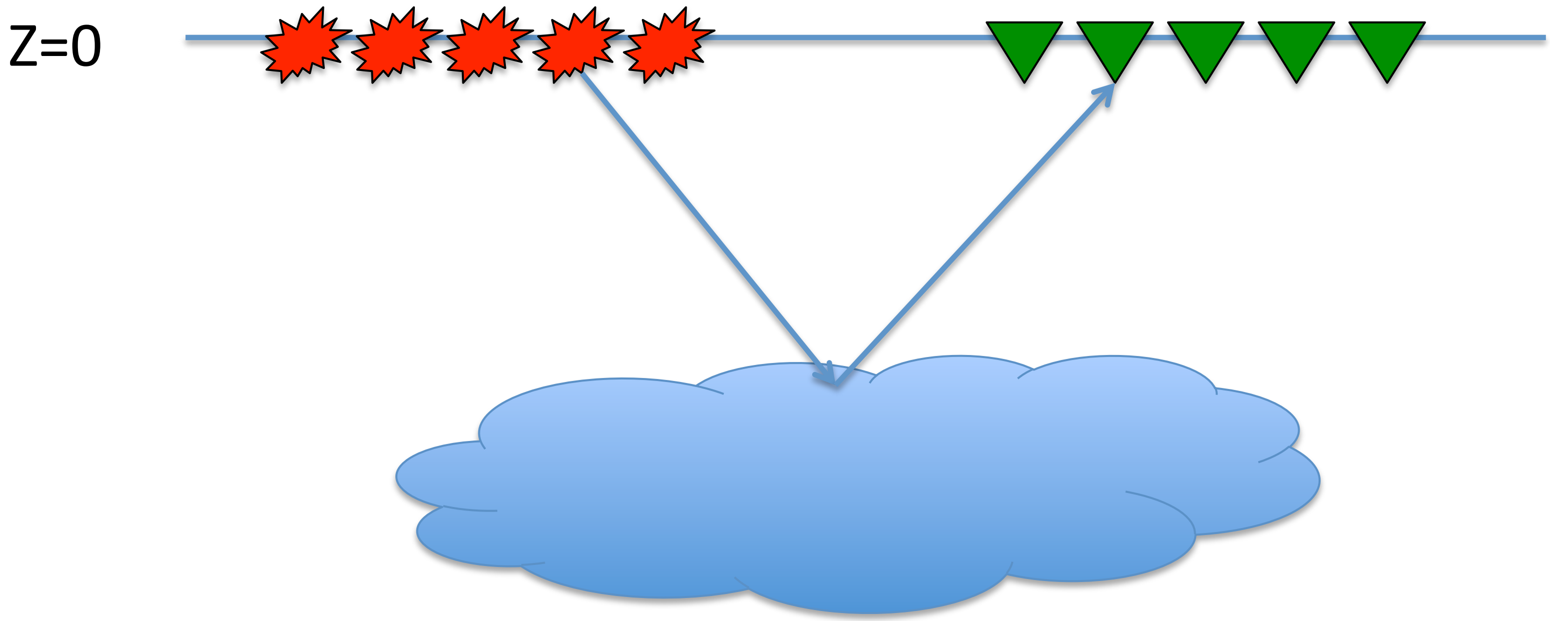

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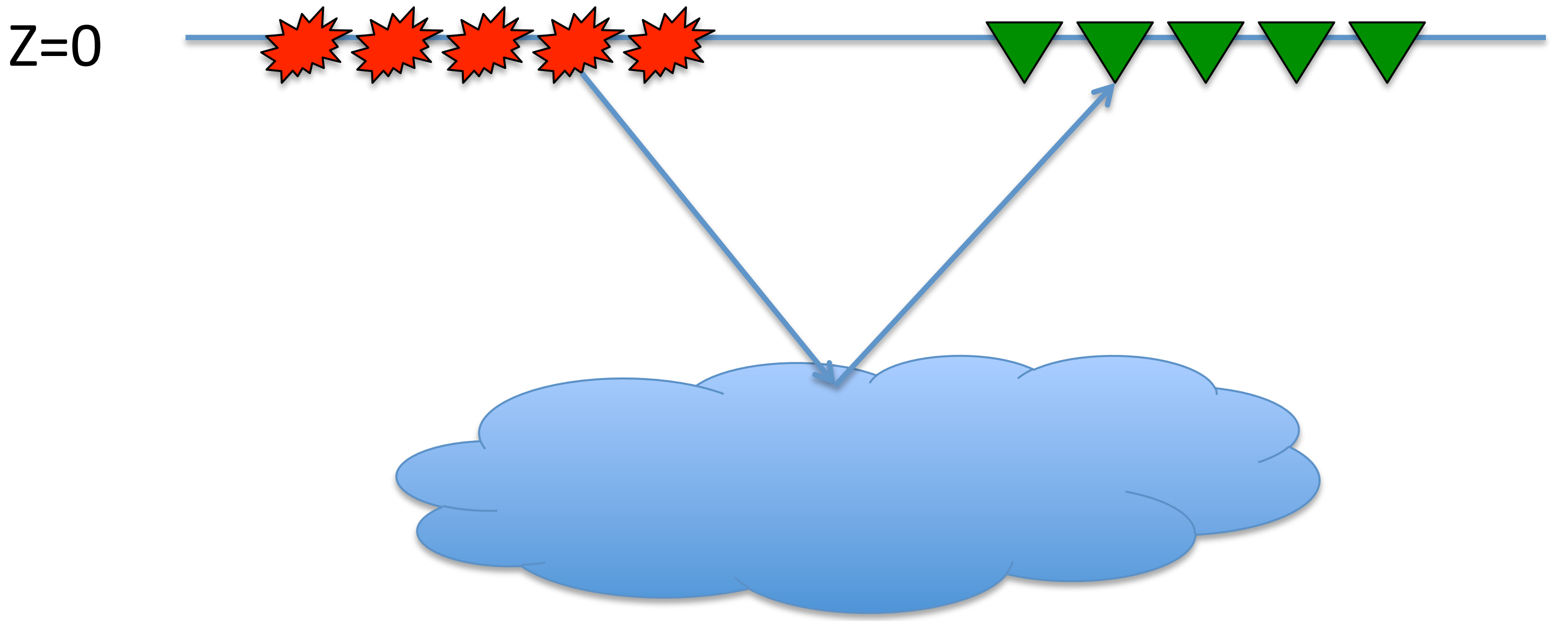

$$D(x_s, x_g, t) \longrightarrow D(k_s, k_g, \omega)$$

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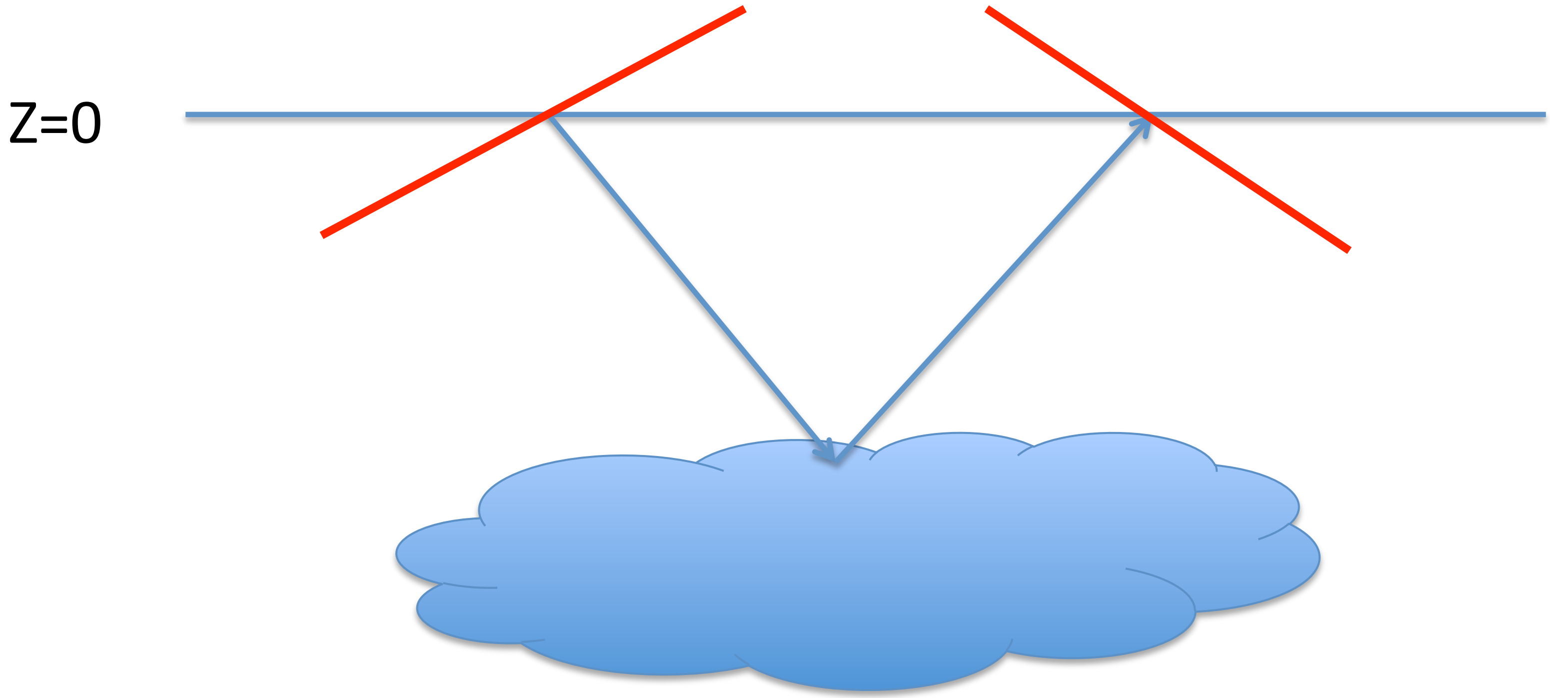

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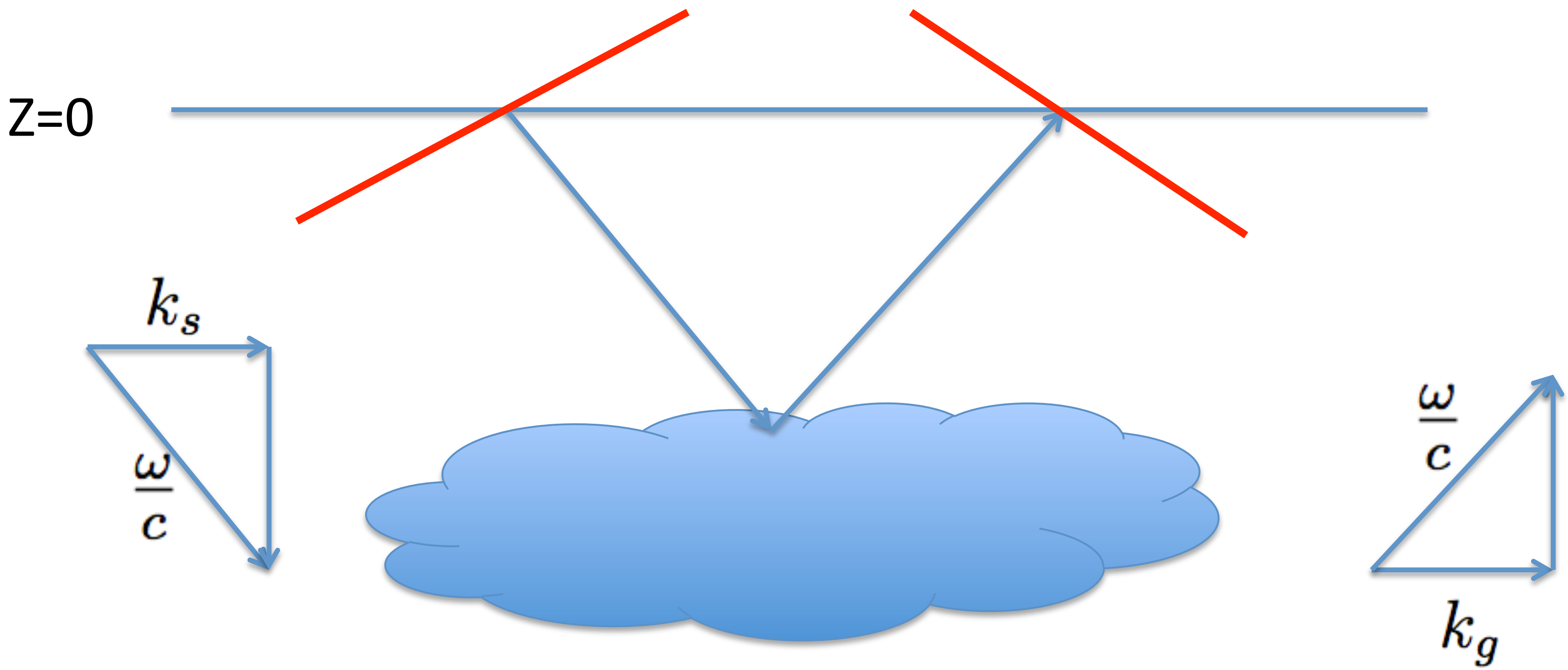

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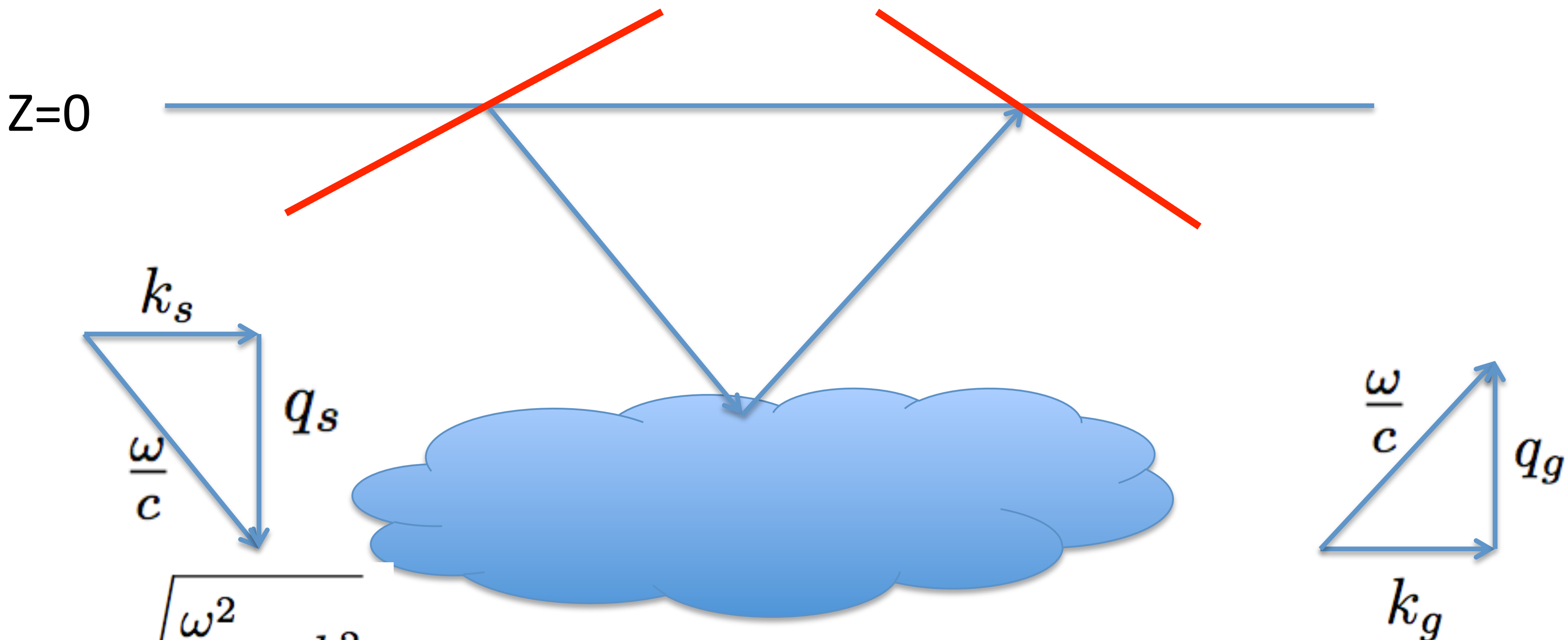

$$q_s = \sqrt{\frac{\omega^2}{c_0^2} - k_s^2}$$

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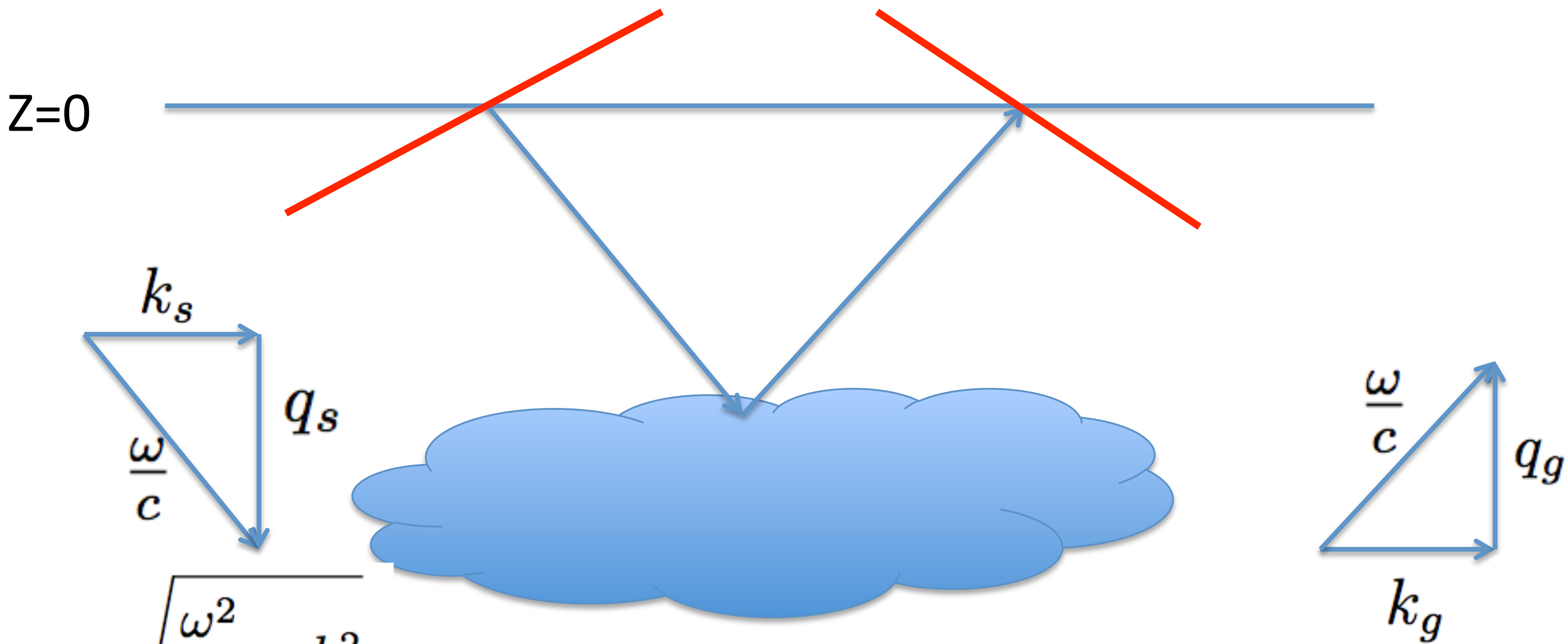

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$$b_1(k_s, k_g, \omega) = -2iq_s D(k_s, k_g, \omega)$$

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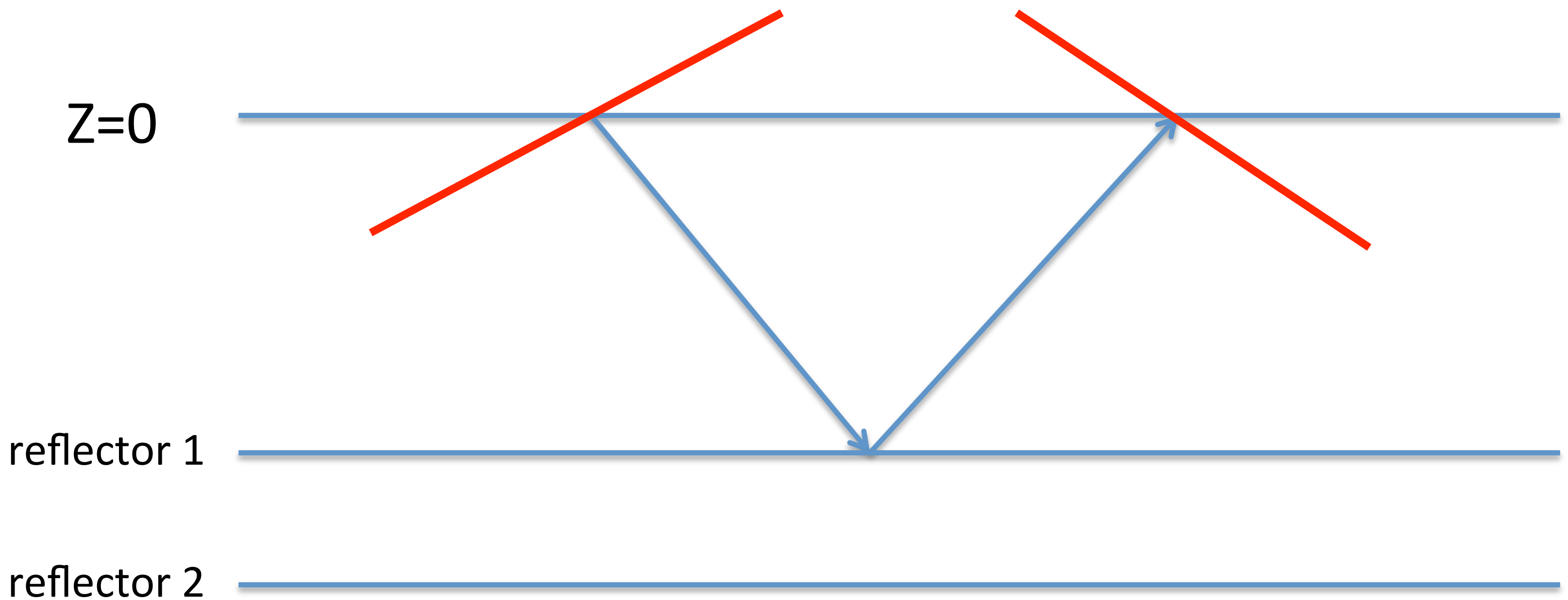

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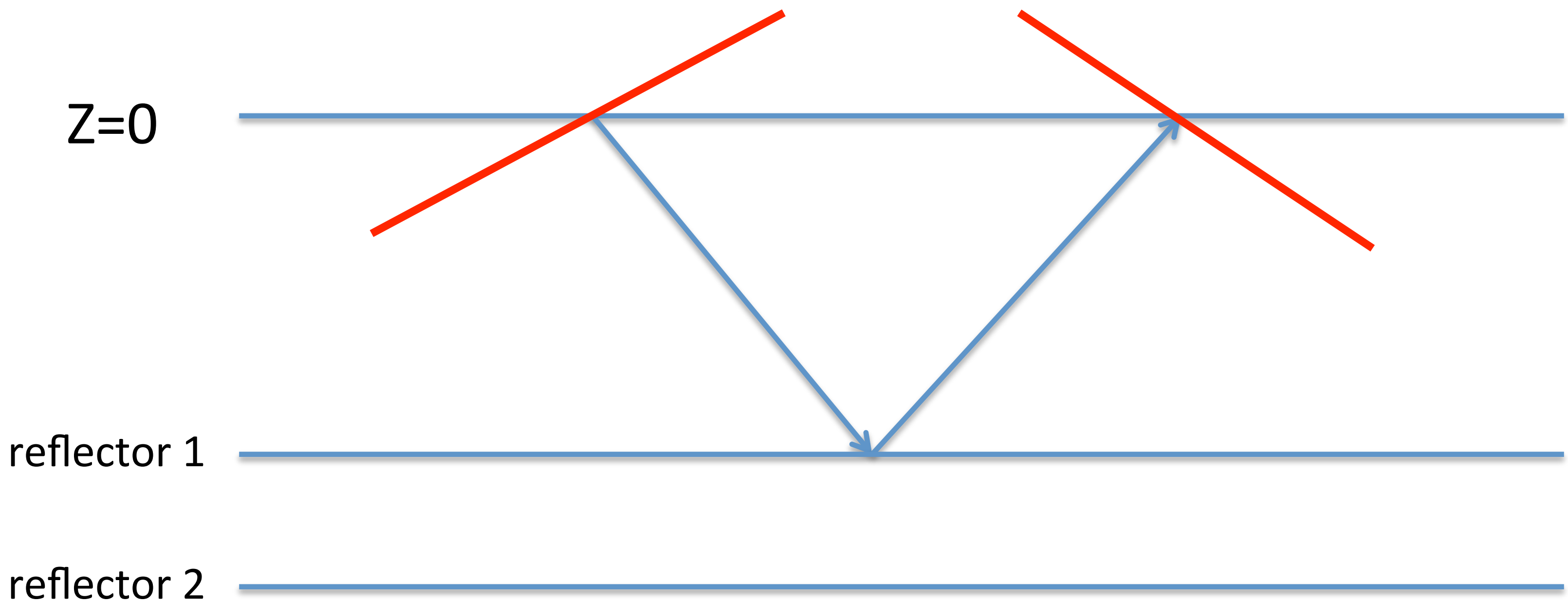

$$b_1(k_s, k_g, \omega) = -2iq_s D(k_s, k_g, \omega)$$

$$b_1(k, \omega) = -2iqD(k, \omega)$$

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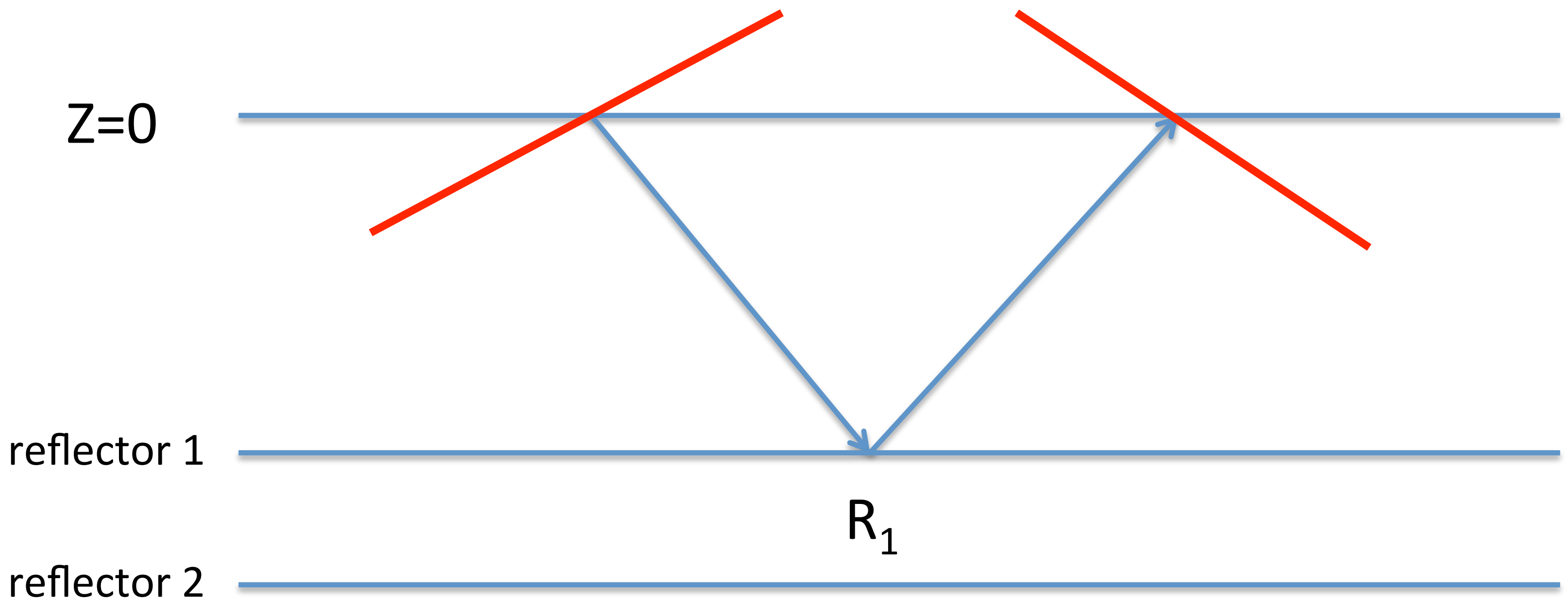

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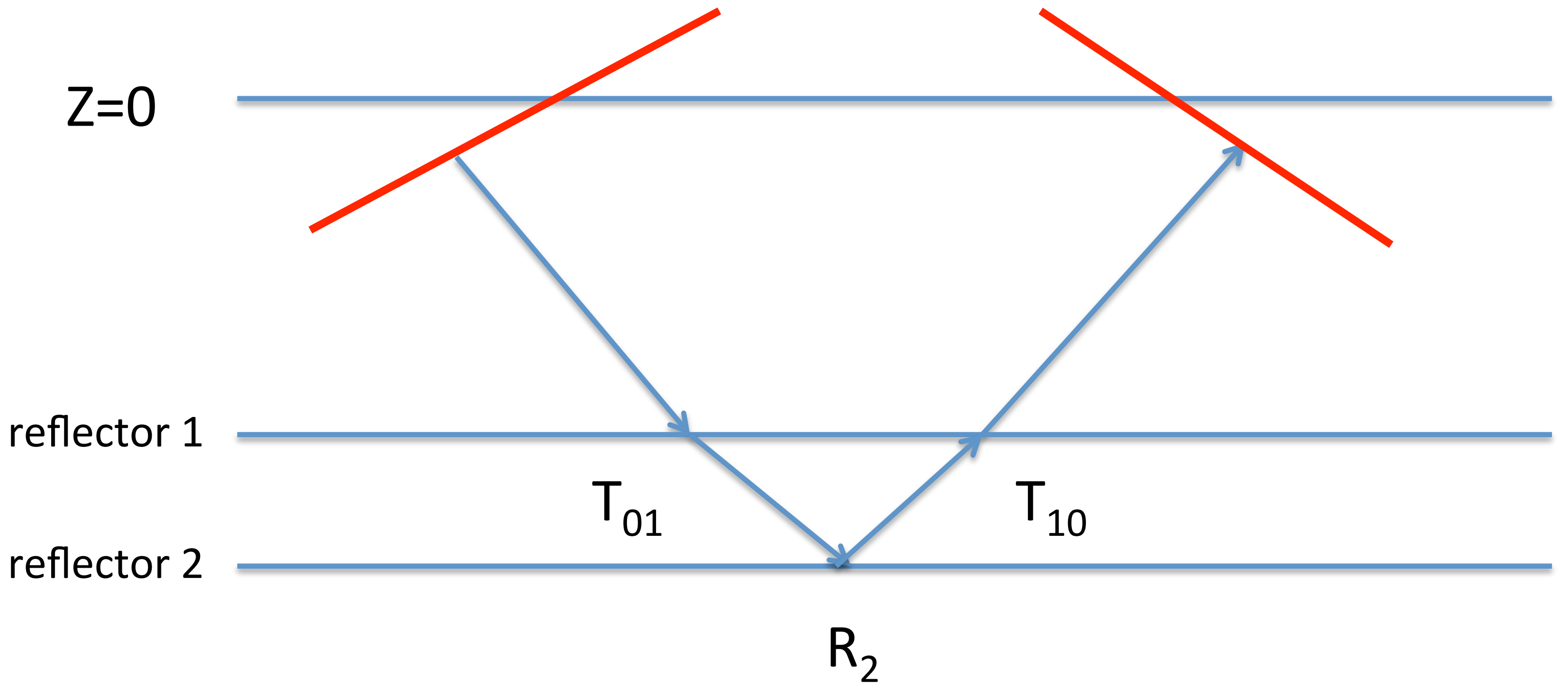

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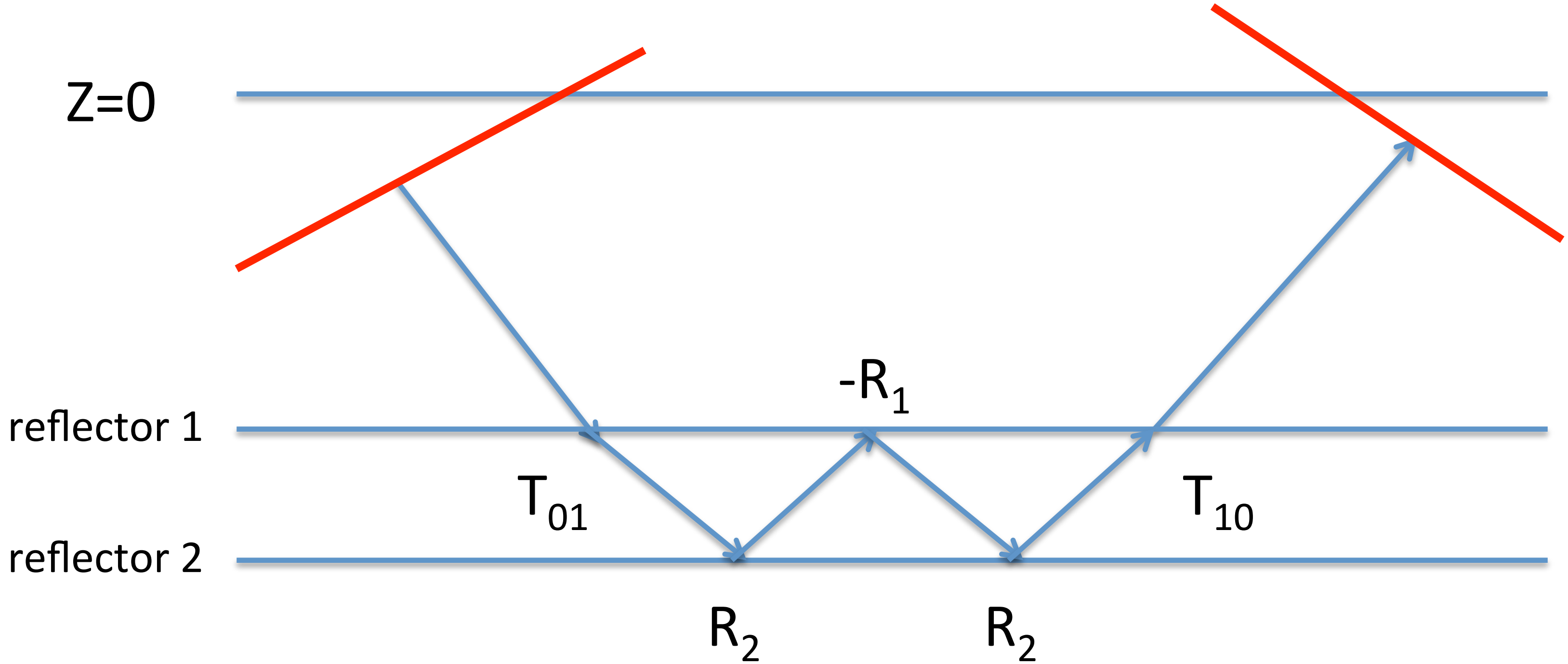

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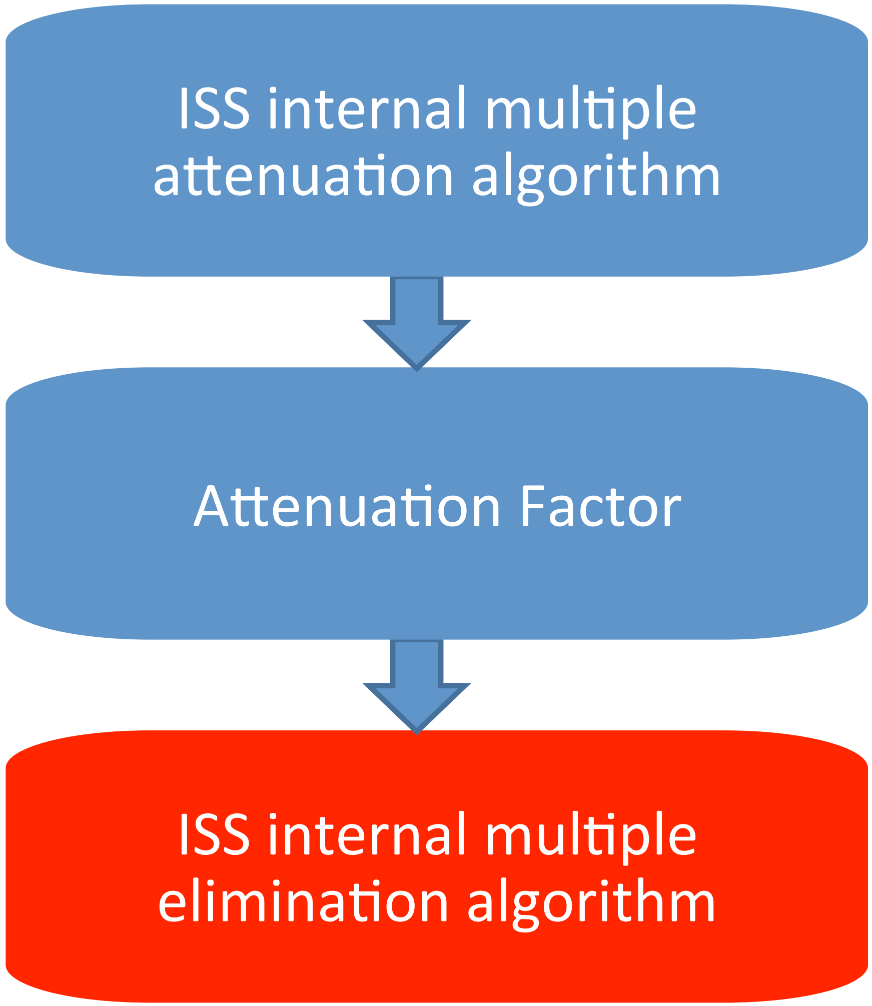
Each T is angle dependent and a function of incident angle.

The structure of this presentation



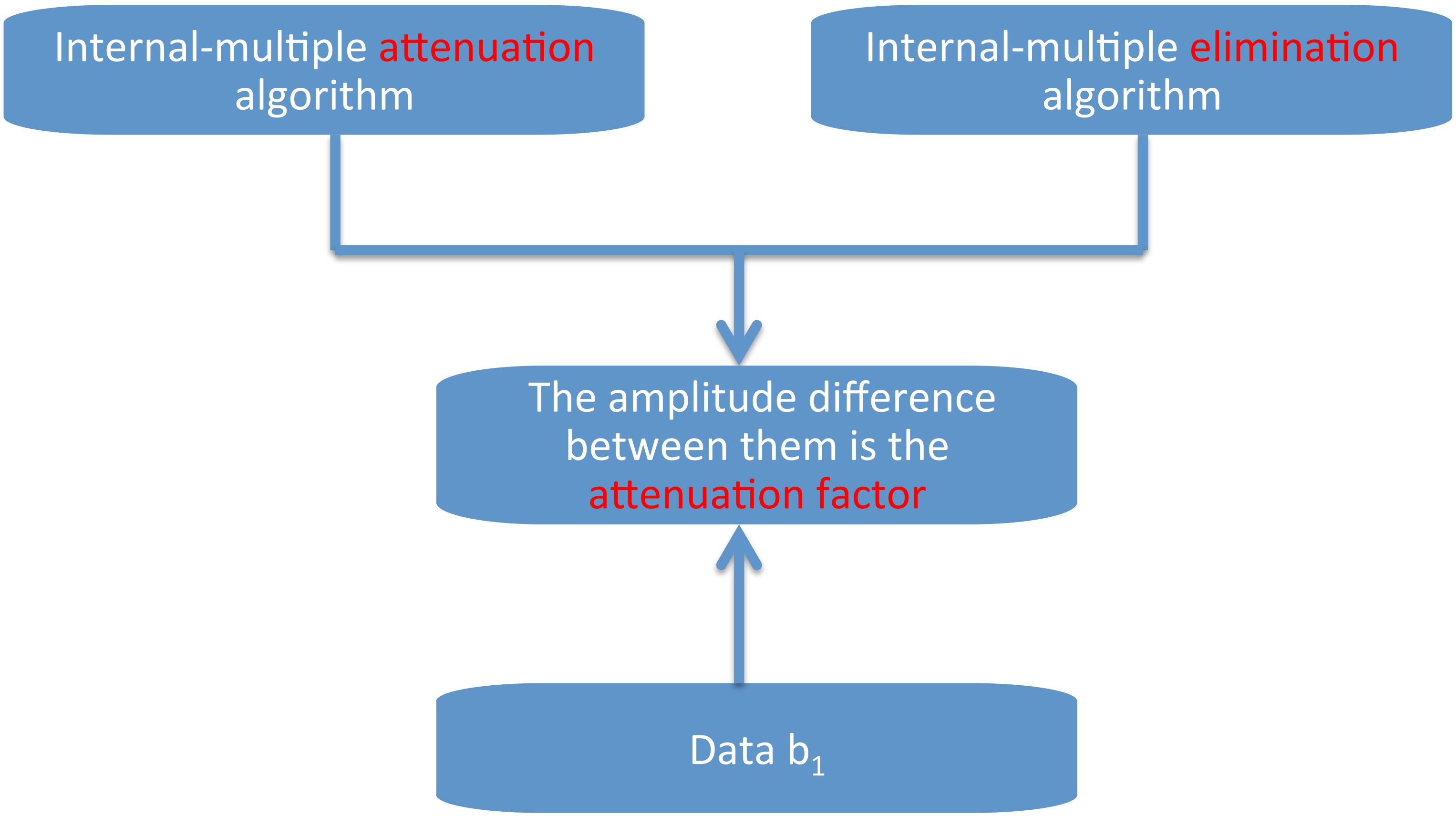
ISS internal multiple elimination

Internal-multiple attenuation algorithm

Internal-multiple elimination algorithm

The amplitude difference between them is the attenuation factor

ISS internal multiple elimination



ISS internal multiple elimination

The reverse engineering way to remove first order internal multiples is to build a new function in the second integral to remove the attenuation factor.

$$b_3(k, 2q) \quad = \quad \int_{-\infty}^{\infty} dz e^{2iqz} b_1(k, z) \int_{-\infty}^{z-\varepsilon_1} dz' e^{-2iqz'} b_1(k, z') \int_{z'+\varepsilon_2}^{\infty} dz'' e^{2iqz''} b_1(k, z'')$$

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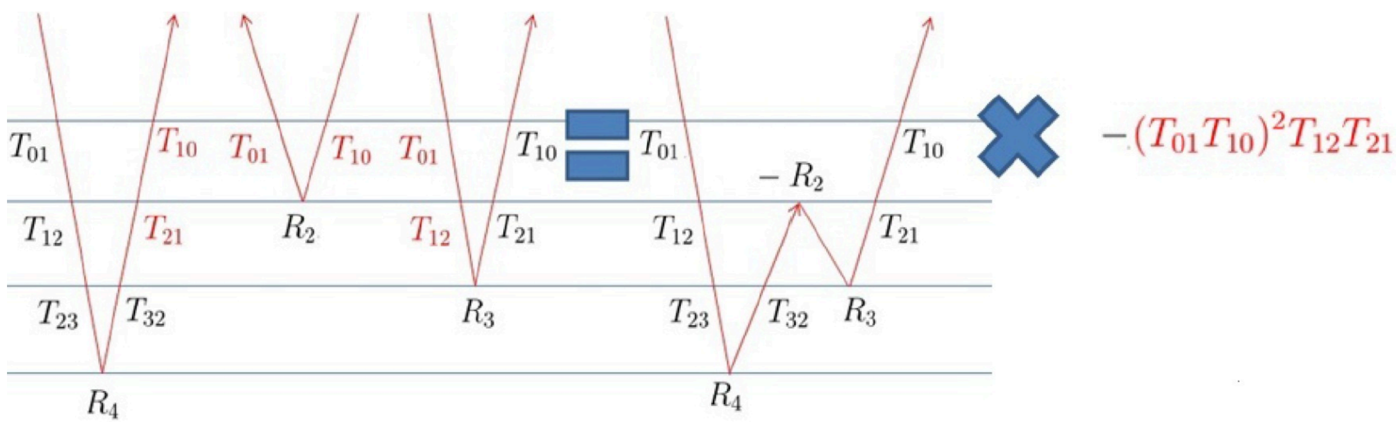

sub-events into ISS attenuator   actual internal multiple   difference (AF)

ISS internal multiple elimination

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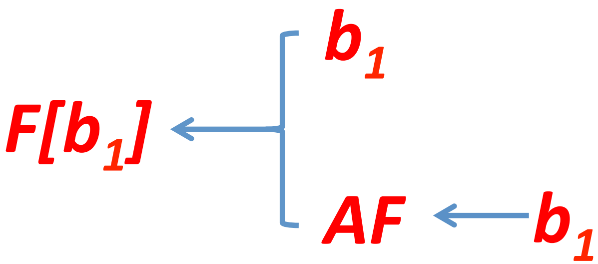
$$b_E^{IM}(k,2q) = \int_{-\infty}^{\infty} dz e^{2iqz} b_1(k,z) \int_{-\infty}^{z-\varepsilon_1} dz' e^{-2iqz'} F[b_1(k,z')] \int_{z'+\varepsilon_2}^{\infty} dz'' e^{2iqz''} b_1(k,z'')$$

ISS internal multiple elimination

$$F[b_1] \leftarrow \begin{cases} b_1 \\ AF \end{cases}$$

ISS internal multiple elimination



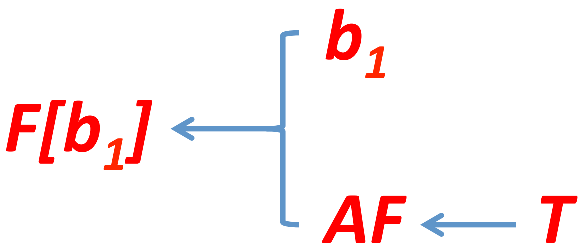
ISS internal multiple elimination

$$F[b_1] \leftarrow \begin{cases} b_1 \\ AF \end{cases}$$

The amplitude of events in $F[b_1]$ should be:

$$\frac{R_i'}{AF_i}$$

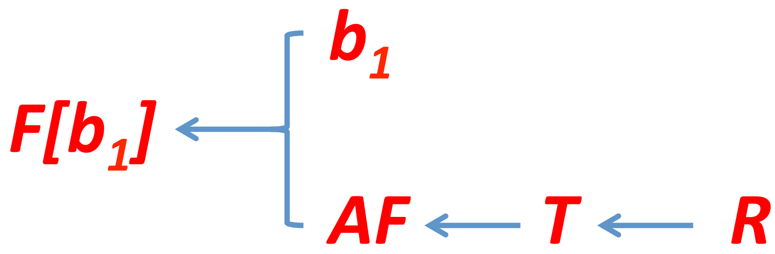
ISS internal multiple elimination



The amplitude of events in F[b_1] should be:

$$\frac{R_i'}{AF_i} = \frac{R_i'}{(T_{01}T_{10})^2(T_{12}T_{21})^2\cdots(T_{i-2,i-1}T_{i-1,i-2})^2(T_{i-1,i}T_{i,i-1})}$$

ISS internal multiple elimination



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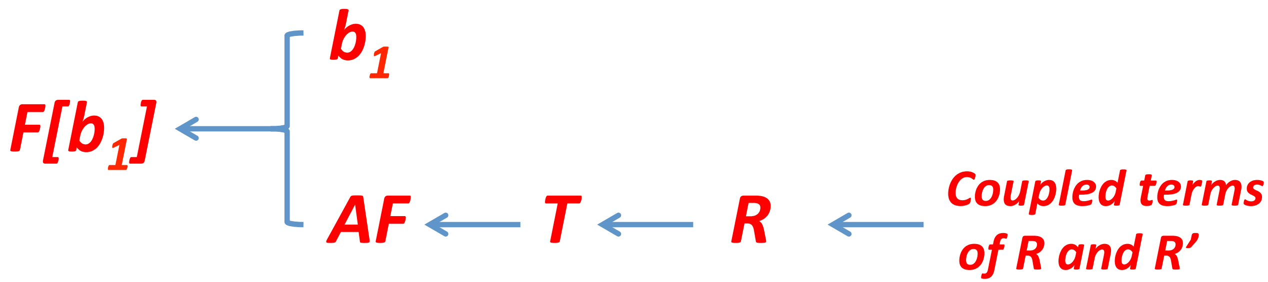
$$= \frac{R_i'}{(1-R_1^2)^2(1-R_2^2)^2\cdots(1-R_{i-1}^2)^2(1-R_i^2)}$$

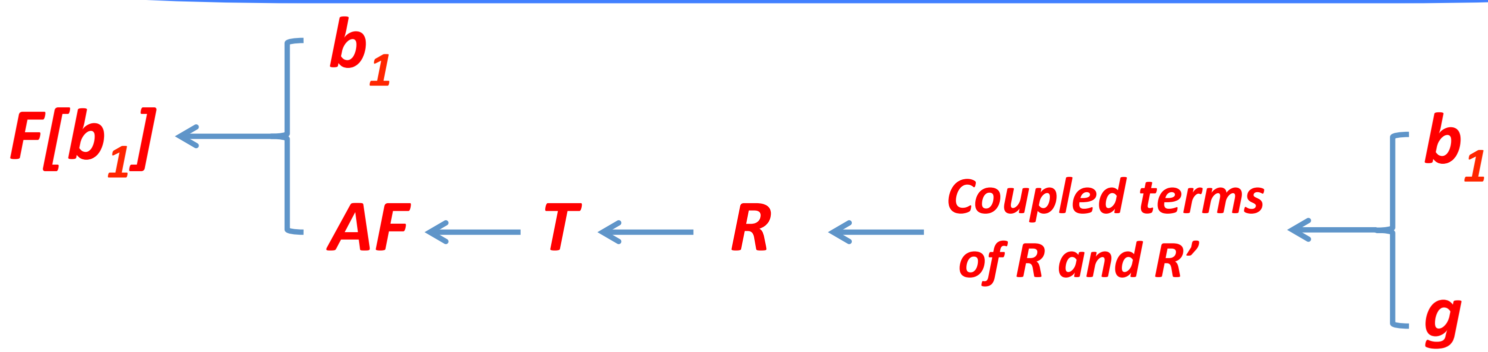
ISS internal multiple elimination



The amplitude of events in F[b_1] should be:

$$
\begin{aligned}
\frac{R'_i}{AF_i} &= \frac{R'_i}{(T_{01}T_{10})^2(T_{12}T_{21})^2\cdots(T_{i-2,i-1}T_{i-1,i-2})^2(T_{i-1,i}T_{i,i-1})} \\
&= \frac{R'_i}{(1-R_1^2)^2(1-R_2^2)^2\cdots(1-R_{i-1}^2)^2(1-R_i^2)} \\
&= \frac{R'_i}{(1-R_1R_1-R'_2R_2-\cdots-R'_{i-1}R_{i-1})^2(1-R_i^2)}
\end{aligned}
$$

ISS internal multiple elimination



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&= \frac{R'_i}{(1-R_1^2)^2(1-R_2^2)^2\cdots(1-R_{i-1}^2)^2(1-R_i^2)} \\
&= \frac{R'_i}{(1-R_1R_1-R'_2R_2-\cdots-R'_{i-1}R_{i-1})^2(1-R_i^2)}
\end{aligned}
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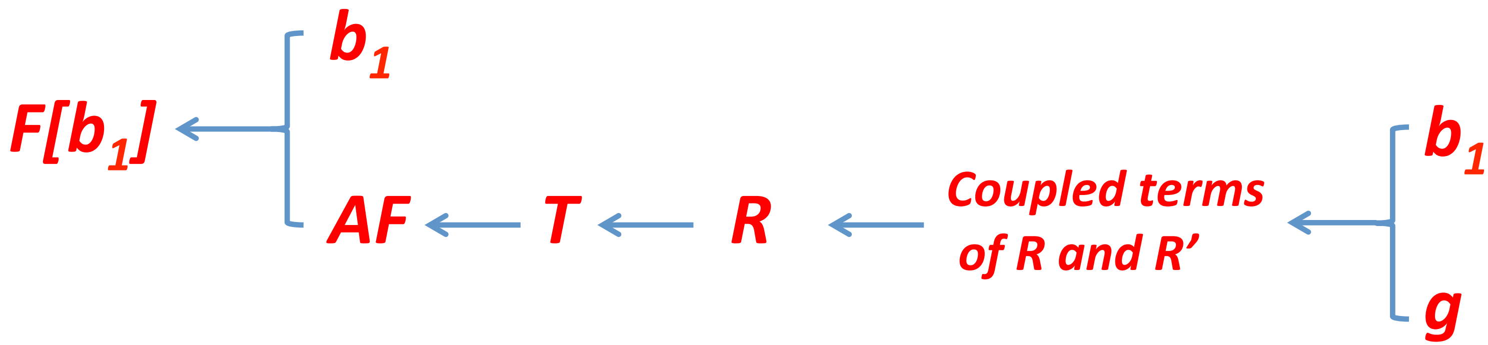
ISS internal multiple elimination



The amplitude of events in F[b_1] should be:

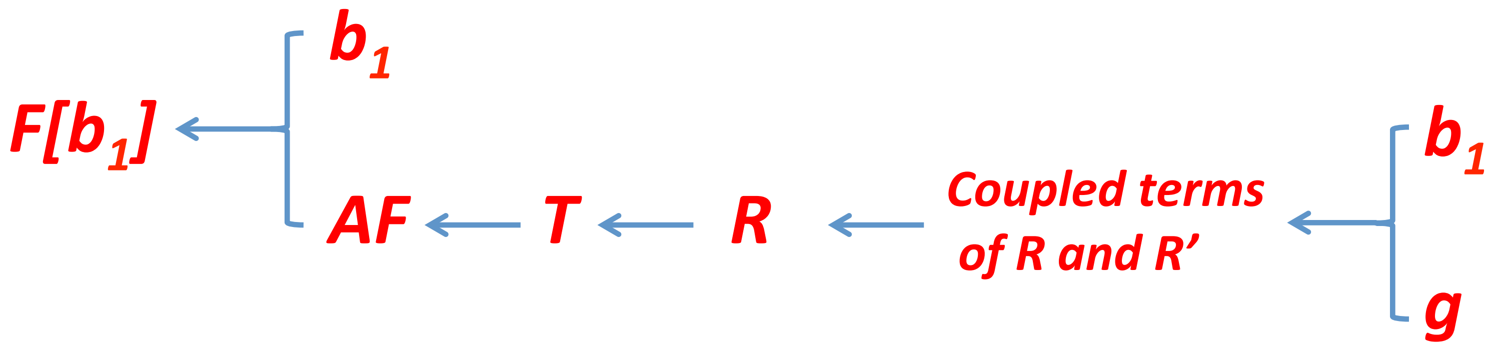
$$\frac{R'_i}{AF_i} = \frac{R'_i}{(T_{01}T_{10})^2(T_{12}T_{21})^2\cdots(T_{i-2,i-1}T_{i-1,i-2})^2(T_{i-1,i}T_{i,i-1})}$$

$$= \frac{R'_i}{(1-R_1^2)^2(1-R_2^2)^2\cdots(1-R_{i-1}^2)^2(1-R_i^2)}$$

$$= \frac{R'_i}{(1-R_1R_1-R'_2R_2-\cdots-R'_{i-1}R_{i-1})^2(1-R_i^2)}$$

$$\int_{z'-\varepsilon}^{z'+\varepsilon} dz'' g(k,z'')e^{iq'z''} \int_{z''-\varepsilon}^{z''+\varepsilon} dz''' g^*(k,z''')e^{-iq'z'''} \longrightarrow R_i^2$$

ISS internal multiple elimination



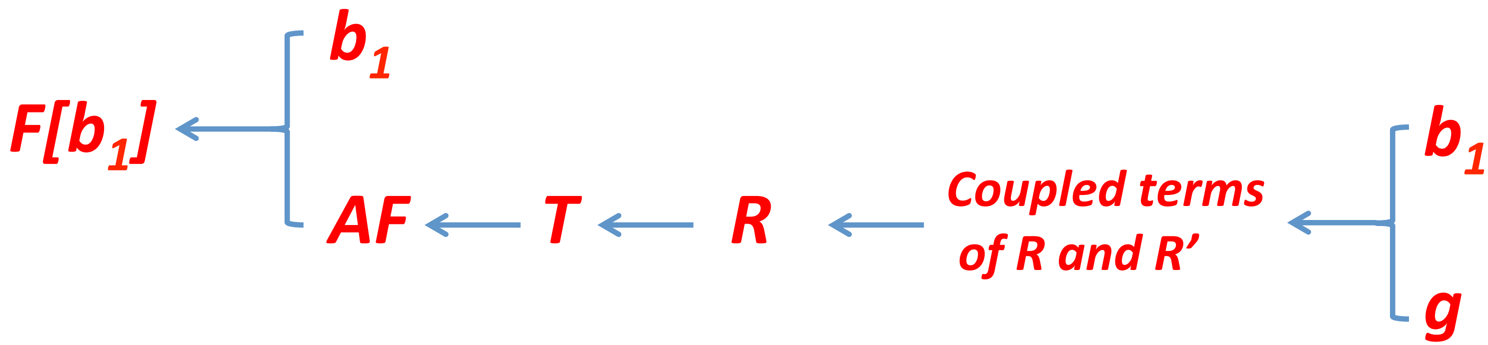
The amplitude of events in F[b_1] should be:

$$
\begin{aligned}
\frac{R_i'}{AF_i} &= \frac{R_i'}{(T_{01}T_{10})^2(T_{12}T_{21})^2\cdots(T_{i-2,i-1}T_{i-1,i-2})^2(T_{i-1,i}T_{i,i-1})} \\
&= \frac{R_i'}{(1-R_1^2)^2(1-R_2^2)^2\cdots(1-R_{i-1}^2)^2(1-R_i^2)} \\
&= \frac{R_i'}{(1-R_1R_1-R_2'R_2-\cdots-R_{i-1}'R_{i-1})^2(1-R_i^2)}
\end{aligned}
$$

$$
\int_{z'-\varepsilon}^{z'+\varepsilon} dz'' g(k,z'') e^{iq'z''} \int_{z''-\varepsilon}^{z''+\varepsilon} dz''' g^*(k,z''') e^{-iq'z'''} \longrightarrow R_i^2
$$

This term is an extension of the self-interaction term in Herrera(2012)

ISS internal multiple elimination



The amplitude of events in $F[b_1]$ should be:

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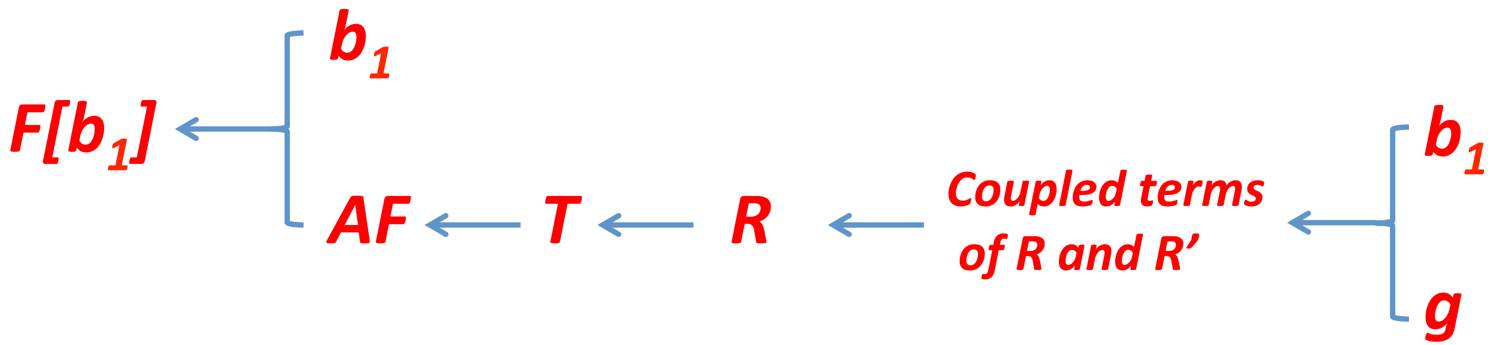
&= \frac{R_i'}{(1-R_1^2)^2(1-R_2^2)^2\cdots(1-R_{i-1}^2)^2(1-R_i^2)} \\
&= \frac{R_i'}{(1-R_1R_1-R_2'R_2-\cdots-R_{i-1}'R_{i-1})^2(1-R_i^2)}
\end{aligned}
$$

$$
\int_{z'-\varepsilon}^{z'+\varepsilon} dz'' g(k,z'')e^{iq'z''} \int_{z''-\varepsilon}^{z''+\varepsilon} dz''' g^*(k,z''')e^{-iq'z'''} \longrightarrow R_i^2
$$

This term is an extension of the self-interaction term in Herrera(2012)

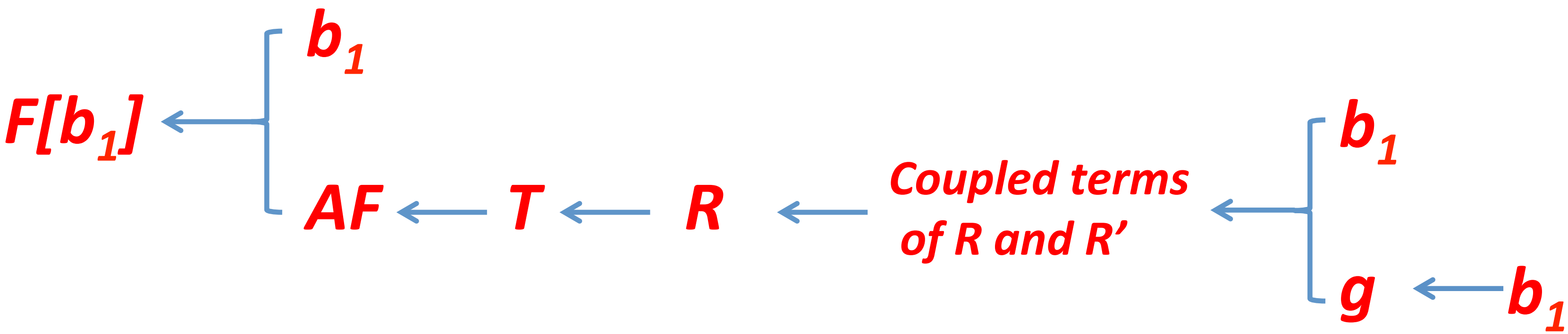
$$
\int_{-\infty}^{z-\varepsilon} dz' b_1(k,z')e^{iq'z'} \int_{z'-\varepsilon}^{z'+\varepsilon} dz'' g^*(k,z'')e^{-iq'z''} \longrightarrow R_1R_1+R_2'R_2+\cdots+R_{i-1}'R_{i-1}
$$

ISS internal multiple elimination

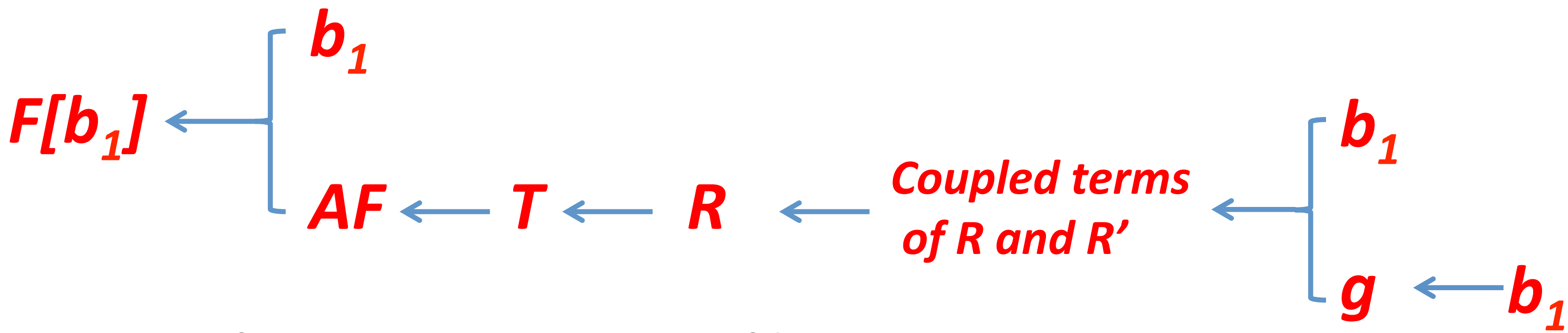


$$F[b_1(k,z)] = \frac{1}{2\pi}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} dz'dq' \times$$
$$\frac{e^{-iq'z}e^{iq'z'}b_1(k,z')}{[1-\int_{-\infty}^{z'-\varepsilon} dz''b_1(k,z'')e^{iq'z''}\int_{z''-\varepsilon}^{z''+\varepsilon} dz'''g^*(k,z''')e^{-iq'z'''}]^2[1-\int_{z'-\varepsilon}^{z'+\varepsilon} dz''g(k,z'')e^{iq'z''}\int_{z''-\varepsilon}^{z''+\varepsilon} dz'''g^*(k,z''')e^{-iq'z'''}]}$$

ISS internal multiple elimination

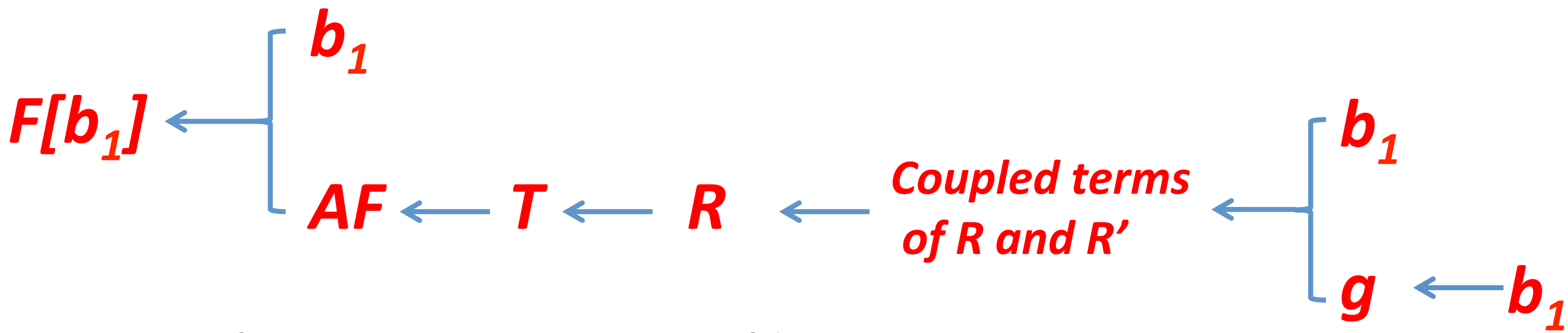


ISS internal multiple elimination



Construct function *g in terms of* b_1:

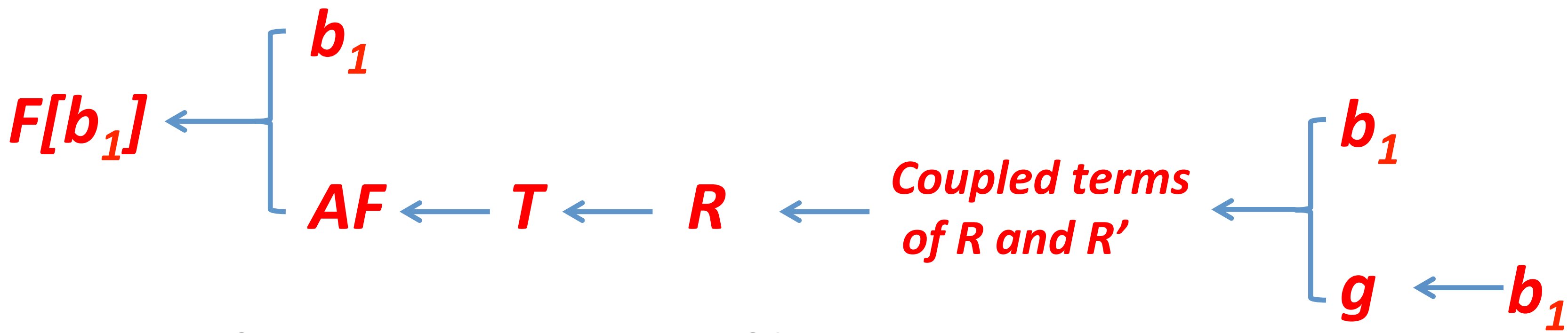
ISS internal multiple elimination



Construct function *g in terms of* b_1:

R_i

ISS internal multiple elimination

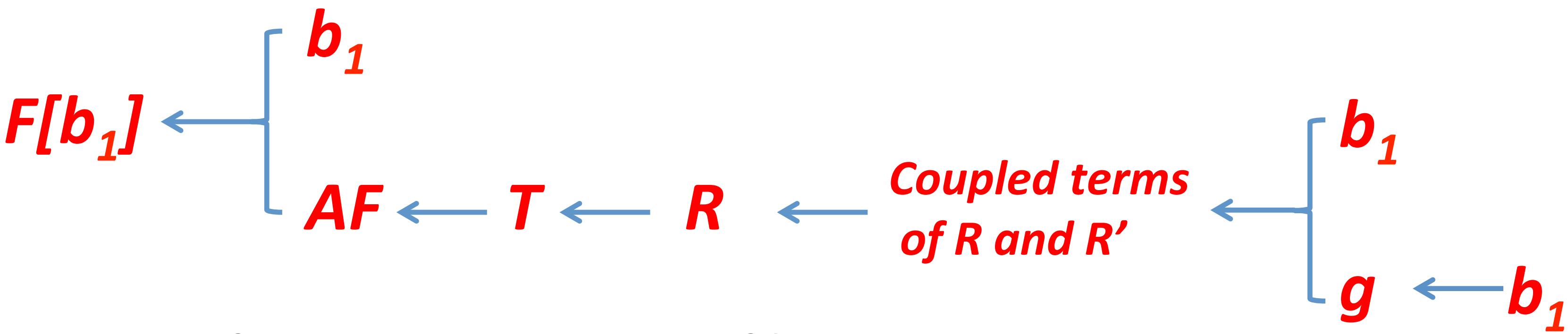


Construct function *g in terms of* b_1*:*

$$R_i = \frac{R_i'}{(1-R_1^2)(1-R_2^2)\cdots(1-R_{i-2}^2)(1-R_{i-1}^2)}$$

$$= \frac{R_i'}{1-R_1R_1-R_2'R_2-\cdots-R_{i-1}'R_{i-1}}$$

ISS internal multiple elimination

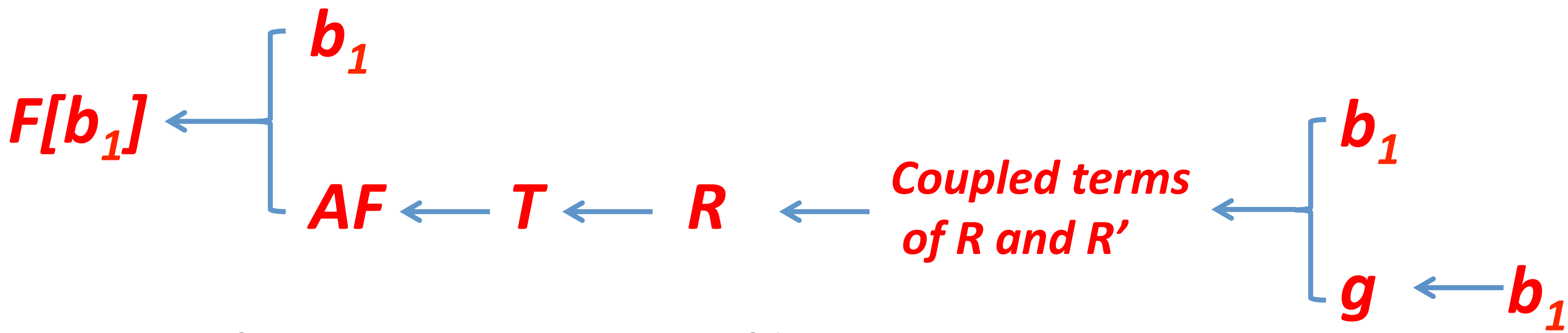


Construct function *g in terms of* b_1*:*

$$R_i = \frac{R'_i}{(1-R_1^2)(1-R_2^2)\cdots(1-R_{i-2}^2)(1-R_{i-1}^2)}$$
$$= \frac{R'_i}{1-R_1R_1-R'_2R_2-\cdots-R'_{i-1}R_{i-1}}$$

$$\int_{-\infty}^{z-\varepsilon} dz' b_1(k,z') e^{iq'z'} \int_{z'-\varepsilon}^{z'+\varepsilon} dz'' g^*(k,z'') e^{-iq'z''} \longrightarrow R_1R_1 + R'_2R_2 + \cdots + R'_{i-1}R_{i-1}$$

ISS internal multiple elimination



Construct function *g in terms of b$_1$:*

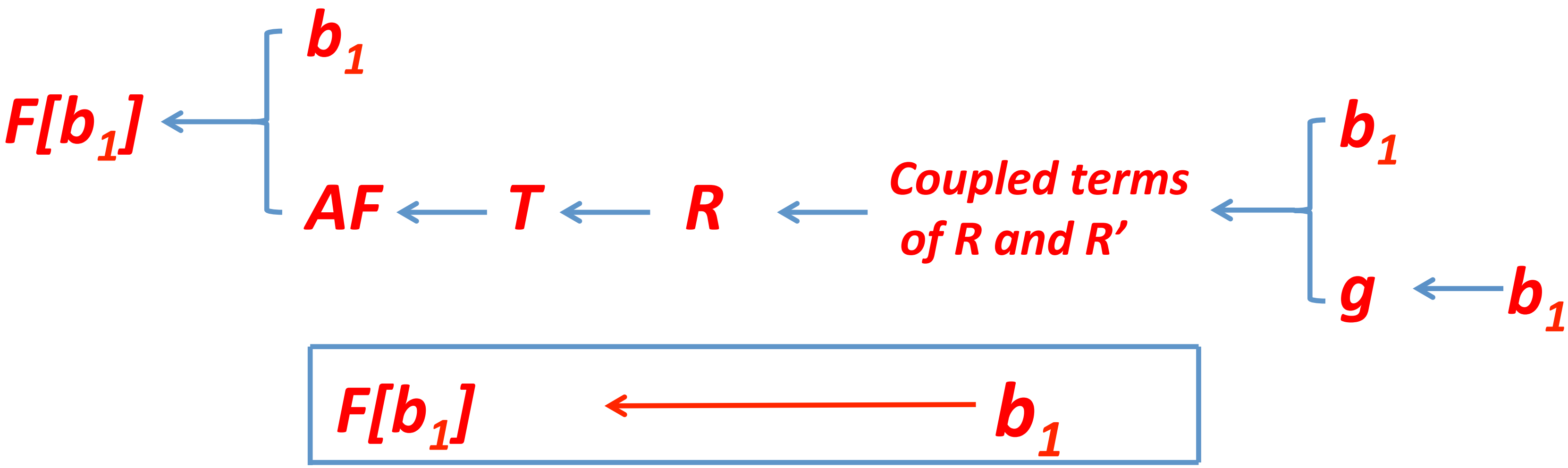
$$R_i = \frac{R_i'}{(1-R_1^2)(1-R_2^2)\cdots(1-R_{i-2}^2)(1-R_{i-1}^2)}$$

$$= \frac{R_i'}{1 - R_1 R_1 - R_2' R_2 - \cdots - R_{i-1}' R_{i-1}}$$

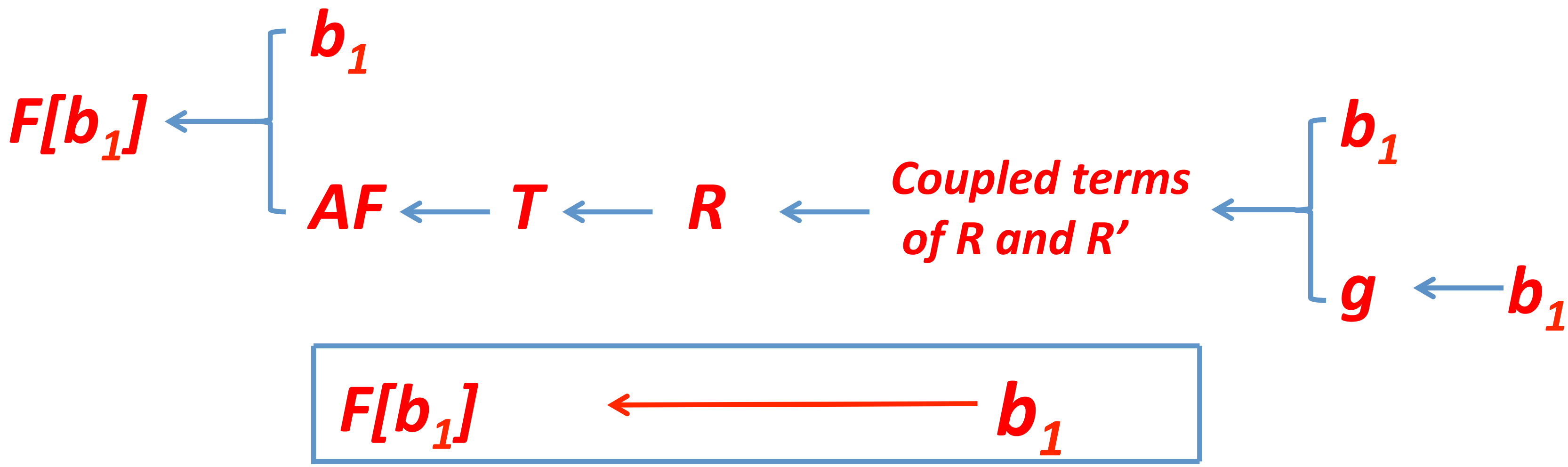
$$\int_{-\infty}^{z-\varepsilon} dz' b_1(k,z') e^{iq'z'} \int_{z'-\varepsilon}^{z'+\varepsilon} dz'' g^*(k,z'') e^{-iq'z''} \longrightarrow R_1 R_1 + R_2' R_2 + \cdots + R_{i-1}' R_{i-1}$$

$$g(k,z) = \frac{1}{2\pi} \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} dz' dq' \frac{e^{-iq'z} e^{iq'z'} b_1(k,z')}{1 - \int_{-\infty}^{z'-\varepsilon} dz'' b_1(k,z'') e^{iq'z''} \int_{z''-\varepsilon}^{z''+\varepsilon} dz''' g^*(k,z''') e^{-iq'z'''}}$$

ISS internal multiple elimination



ISS internal multiple elimination



$$b_E^{IM}(k,2q) = \int_{-\infty}^{\infty} dz e^{2iqz} b_1(k,z) \int_{-\infty}^{z-\varepsilon_1} dz' e^{-2iqz'} F[b_1(k,z')] \int_{z'+\varepsilon_2}^{\infty} dz'' e^{2iqz''} b_1(k,z'')$$

$$\mathrm{F}[\mathrm{b}_1(k,z)] = \frac{1}{2\pi} \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} dz' dq' \times$$

$$\frac{e^{-iq'z} e^{iq'z'} b_1(k,z')}{[1 - \int_{-\infty}^{z'-\varepsilon} dz'' b_1(k,z'') e^{iq'z''} \int_{z''-\varepsilon}^{z''+\varepsilon} dz''' g^*(k,z''') e^{-iq'z'''}]^2 [1 - \int_{z'-\varepsilon}^{z'+\varepsilon} dz'' g(k,z'') e^{iq'z''} \int_{z''-\varepsilon}^{z''+\varepsilon} dz''' g^*(k,z''') e^{-iq'z'''}]}$$

$$g(k,z) = \frac{1}{2\pi} \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} dz' dq' \frac{e^{-iq'z} e^{iq'z'} b_1(k,z')}{1 - \int_{-\infty}^{z'-\varepsilon} dz'' b_1(k,z'') e^{iq'z''} \int_{z''-\varepsilon}^{z''+\varepsilon} dz''' g^*(k,z''') e^{-iq'z'''}}$$

ISS internal multiple elimination

Flow chart of the elimination algorithm

Input: data $D(k,\omega)$

$$b_1(k,\omega) = -2iqD(k,\omega)$$

$$g(k,z) = \frac{1}{2\pi}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} dz'dq' \frac{e^{-iq'z}e^{iq'z'}b_1(k,z')}{1-\int_{-\infty}^{z'-\varepsilon} dz''b_1(k,z'')e^{iq'z''}\int_{z''-\varepsilon}^{z''+\varepsilon} dz'''g^*(k,z''')e^{-iq'z'''}}$$

$$F[b_1(k,z)] = \frac{1}{2\pi}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} dz'dq' \times$$

$$\frac{e^{-iq'z}e^{iq'z'}b_1(k,z')}{[1-\int_{-\infty}^{z'-\varepsilon} dz''b_1(k,z'')e^{iq'z''}\int_{z''-\varepsilon}^{z''+\varepsilon} dz'''g^*(k,z''')e^{-iq'z'''}]^2[1-\int_{z'-\varepsilon}^{z'+\varepsilon} dz''g(k,z'')e^{iq'z''}\int_{z''-\varepsilon}^{z''+\varepsilon} dz'''g^*(k,z''')e^{-iq'z'''}]}$$

$$b_E^{IM}(k,2q) = \int_{-\infty}^{\infty} dz e^{2iqz}b_1(k,z)\int_{-\infty}^{z-\varepsilon_1} dz'e^{-2iqz'}F[b_1(k,z')]\int_{z'+\varepsilon_2}^{\infty} dz''e^{2iqz''}b_1(k,z'')$$

Output: internal multiples with correct time and amplitude $b_E^{IM}(k,2q)$

Test 1: 1D normal incidence

ISS internal multiple elimination

Test 1—model

V=1500m/s ρ=1.0g/cm^3

500m

V=1700m/s ρ=1.8g/cm^3

1700m

V=1700m/s ρ=1.0g/cm^3

2700m

V=3500m/s ρ=4.0g/cm^3

5700m

V=5000m/s ρ=4.0g/cm^3

ISS internal multiple elimination

Test 1

A. Test for perfect data.
B. Test for bandlimited data.
C. Test for data with white noise.

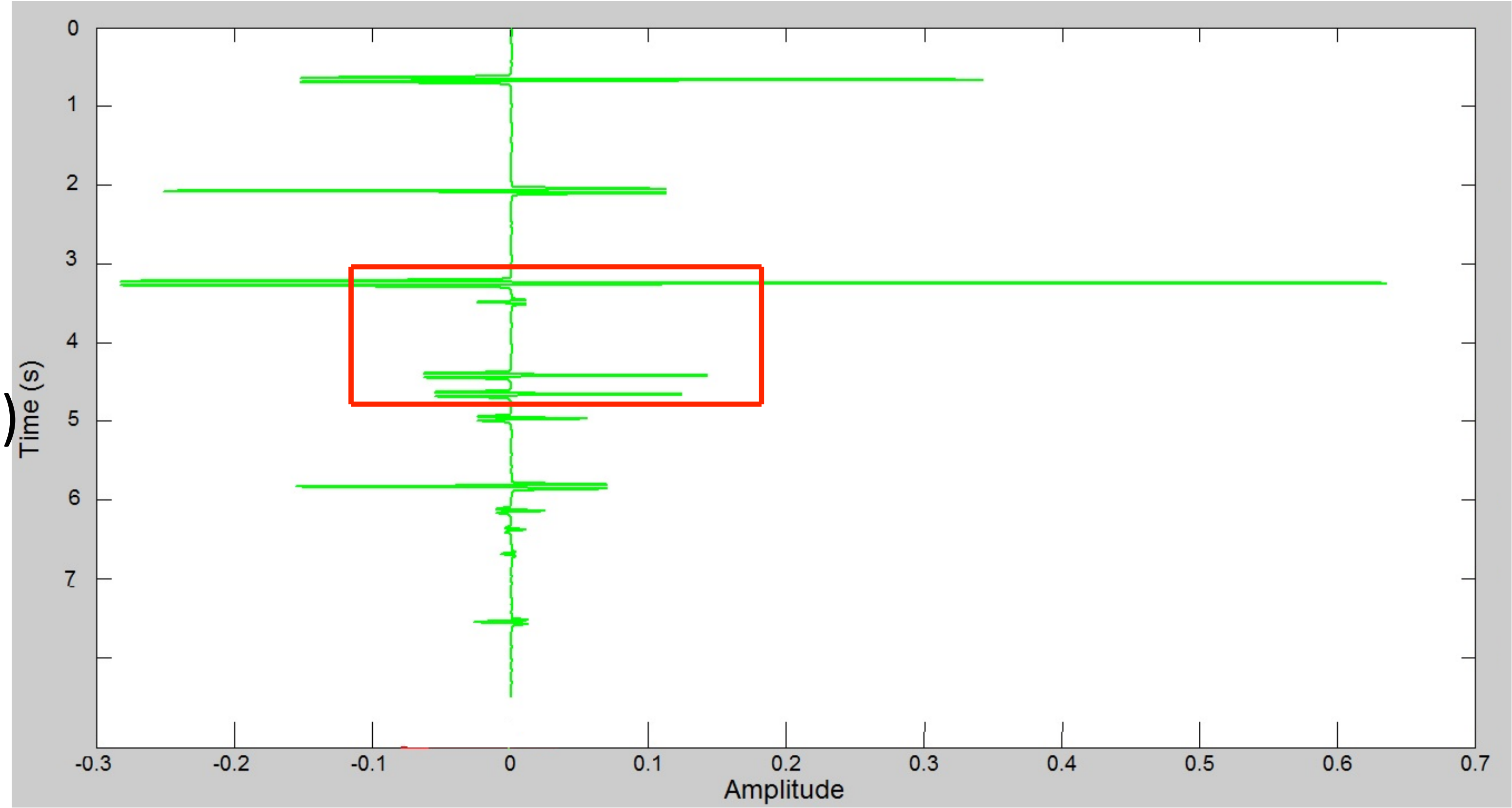
ISS internal multiple elimination

Test 1 — perfect data

A. Test for perfect data.
B. Test for bandlimited data.
C. Test for data with white noise.

ISS internal multiple elimination

Test 1—input data (1D normal incidence)

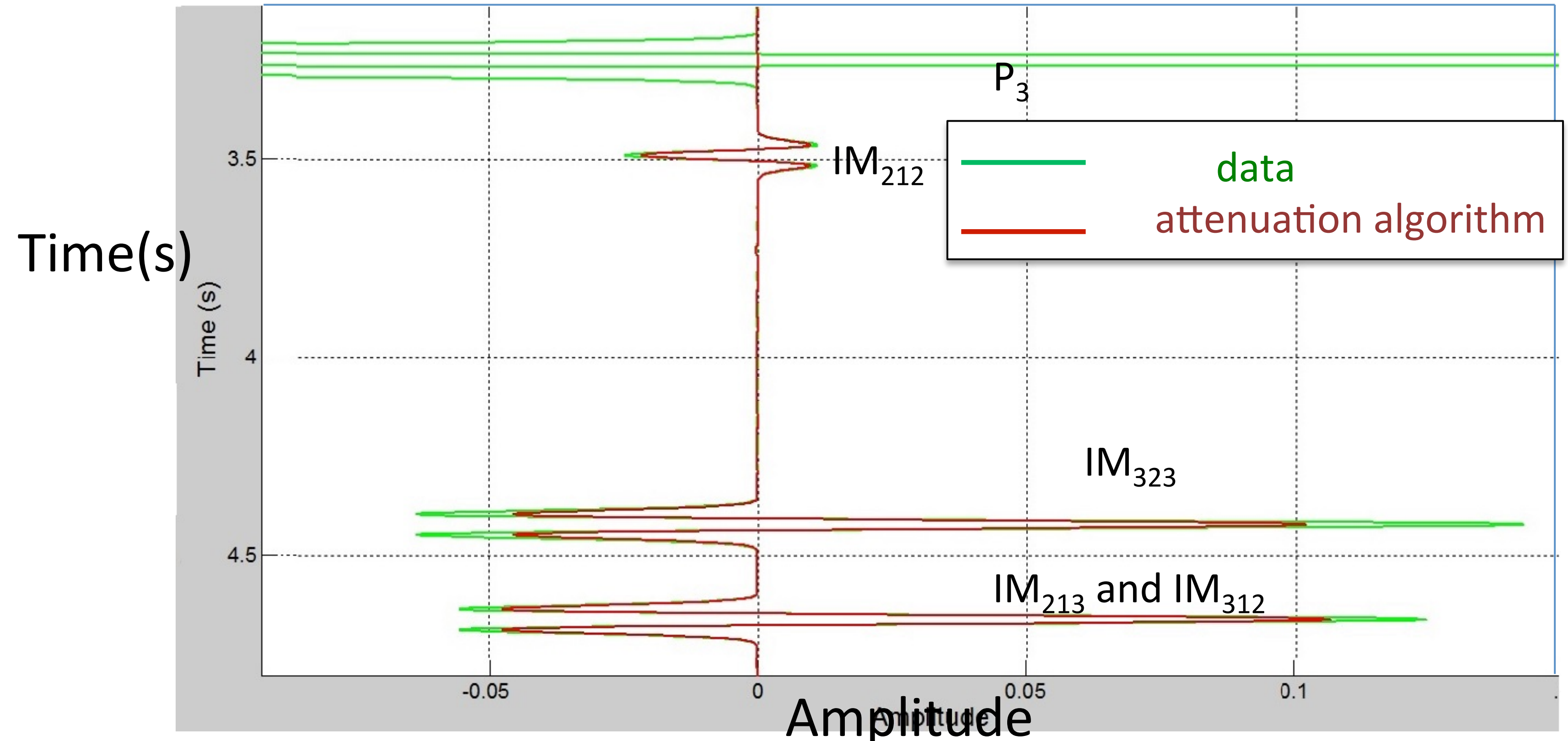


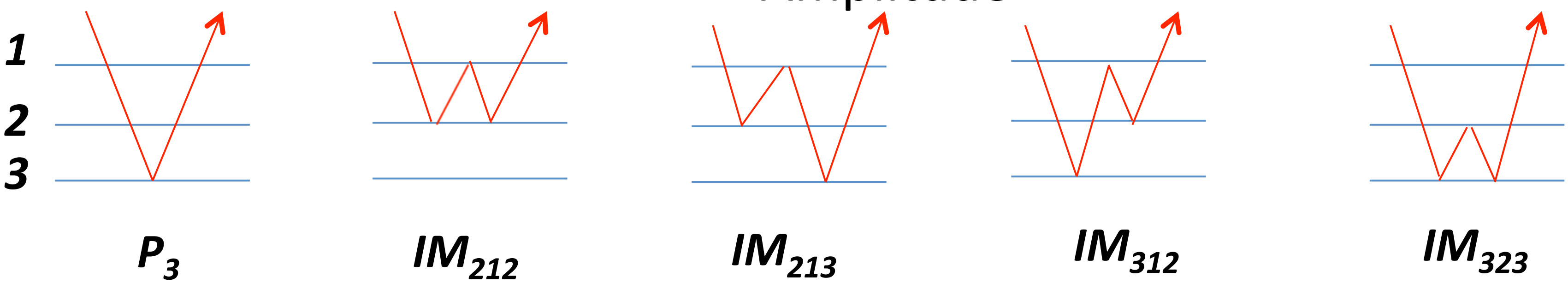
Time(s)

Amplitude

ISS internal multiple elimination

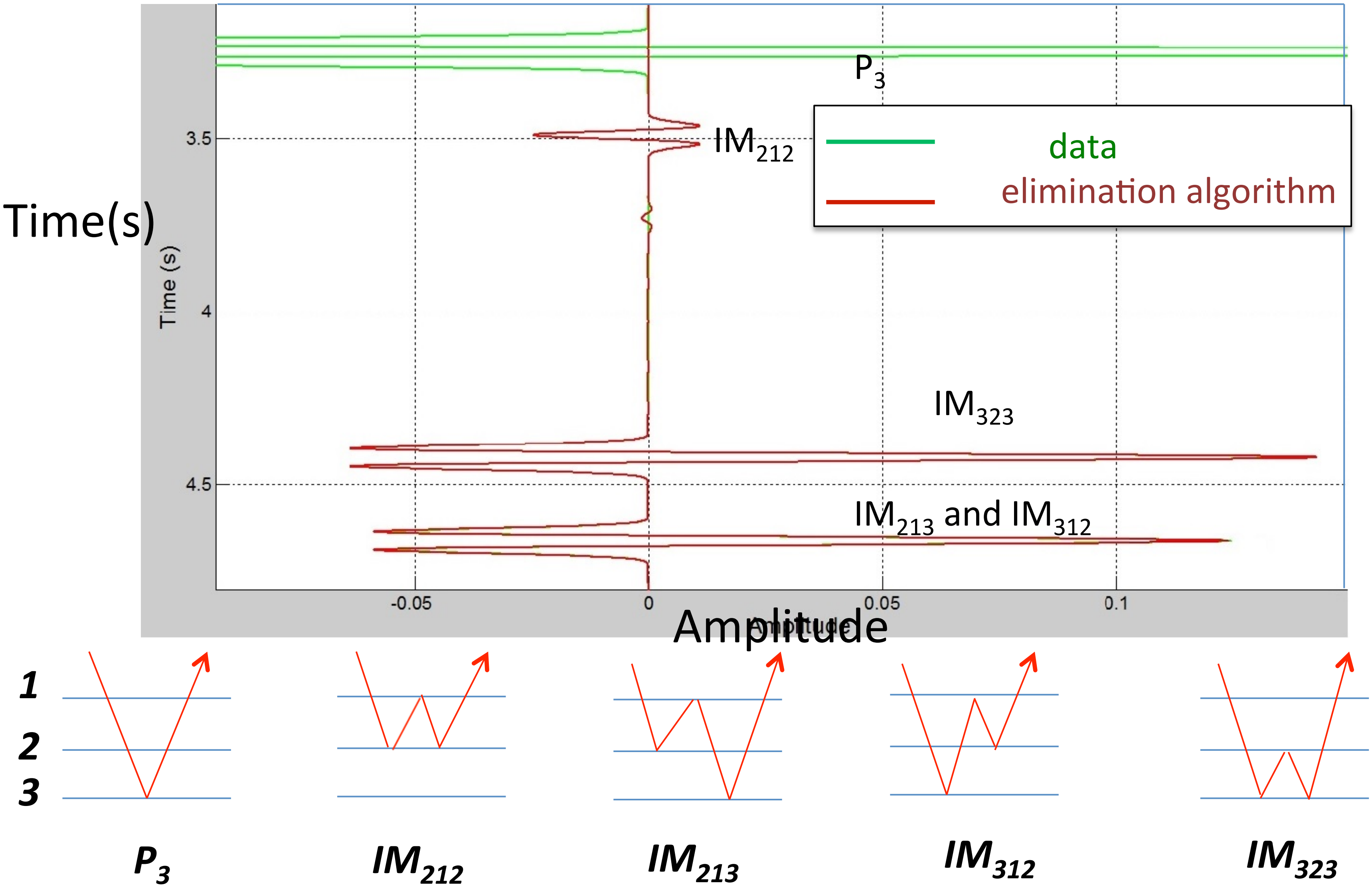
Test 1 — perfect data, attenuation algorithm prediction





ISS internal multiple elimination

Test 1—perfect data, elimination algorithm prediction



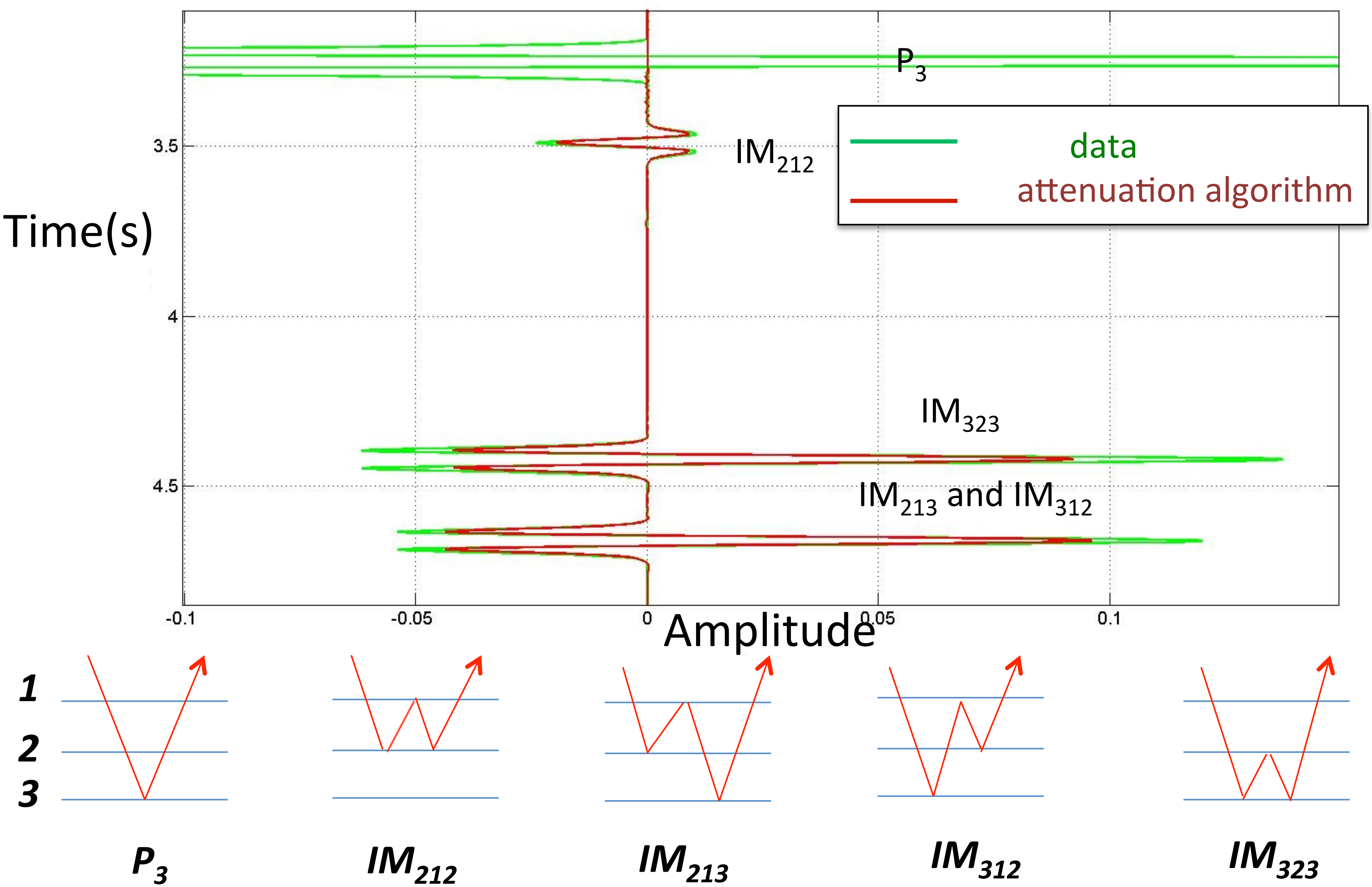
ISS internal multiple elimination

Test 1 — bandlimited data

A. Test for perfect data.
B. Test for bandlimited data.
C. Test for data with white noise.

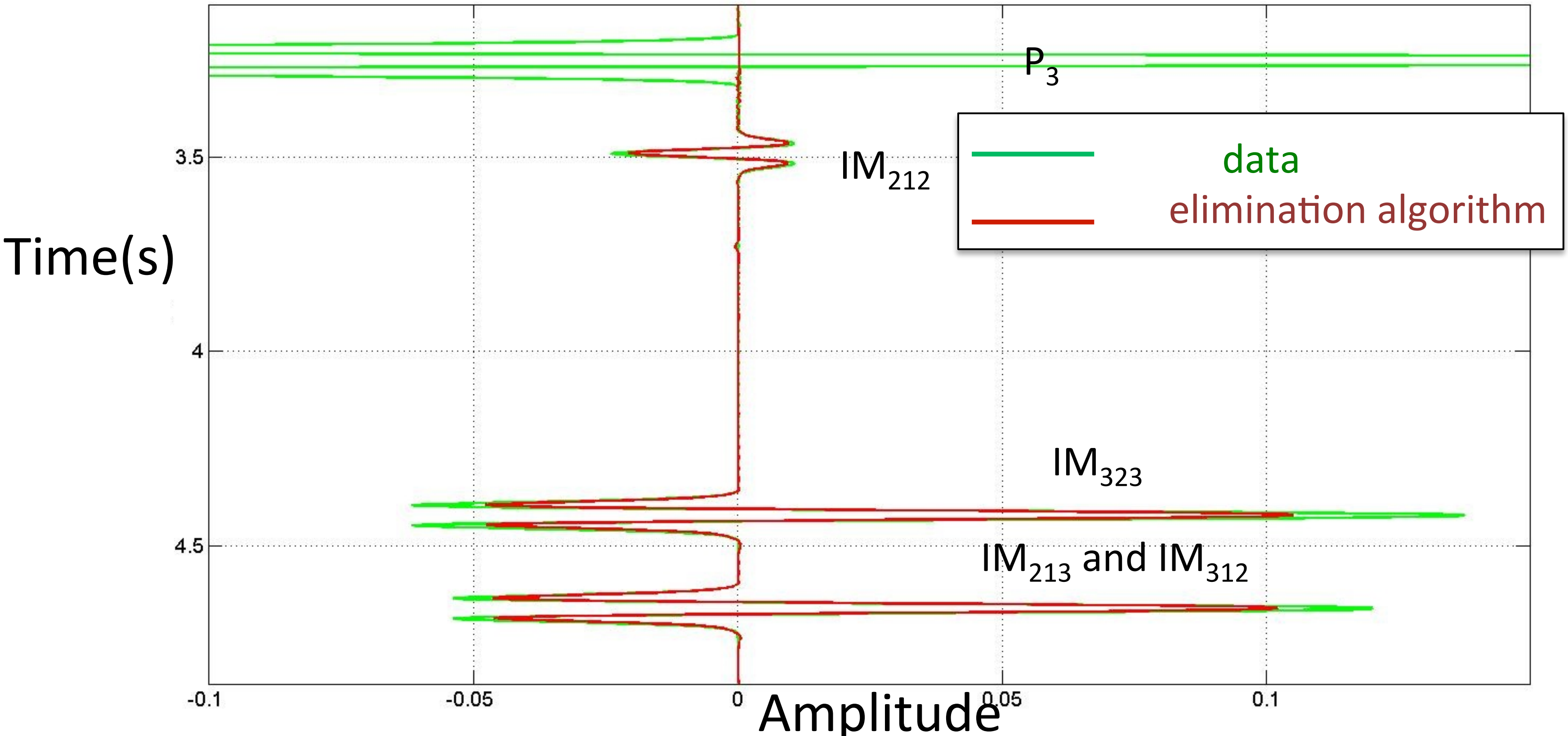
ISS internal multiple elimination

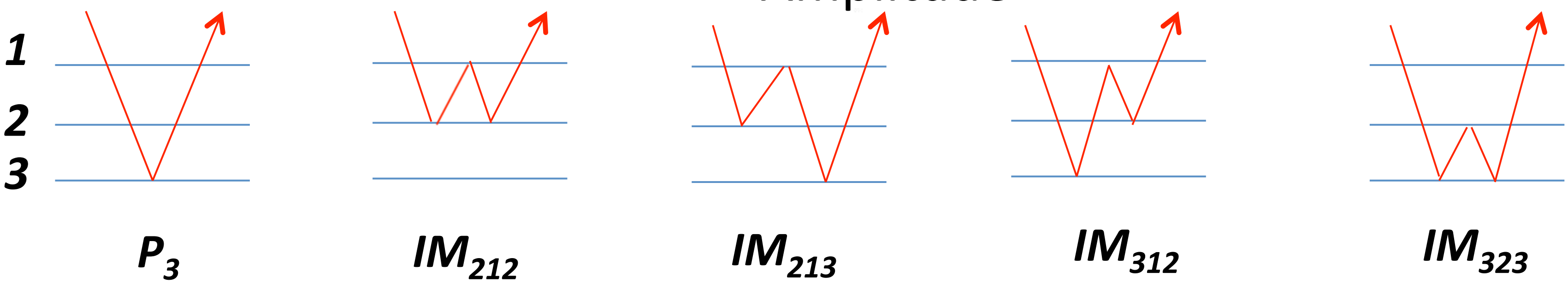
Test 1 — perfect data, attenuation algorithm prediction



ISS internal multiple elimination

Test 1 — perfect data, elimination algorithm prediction





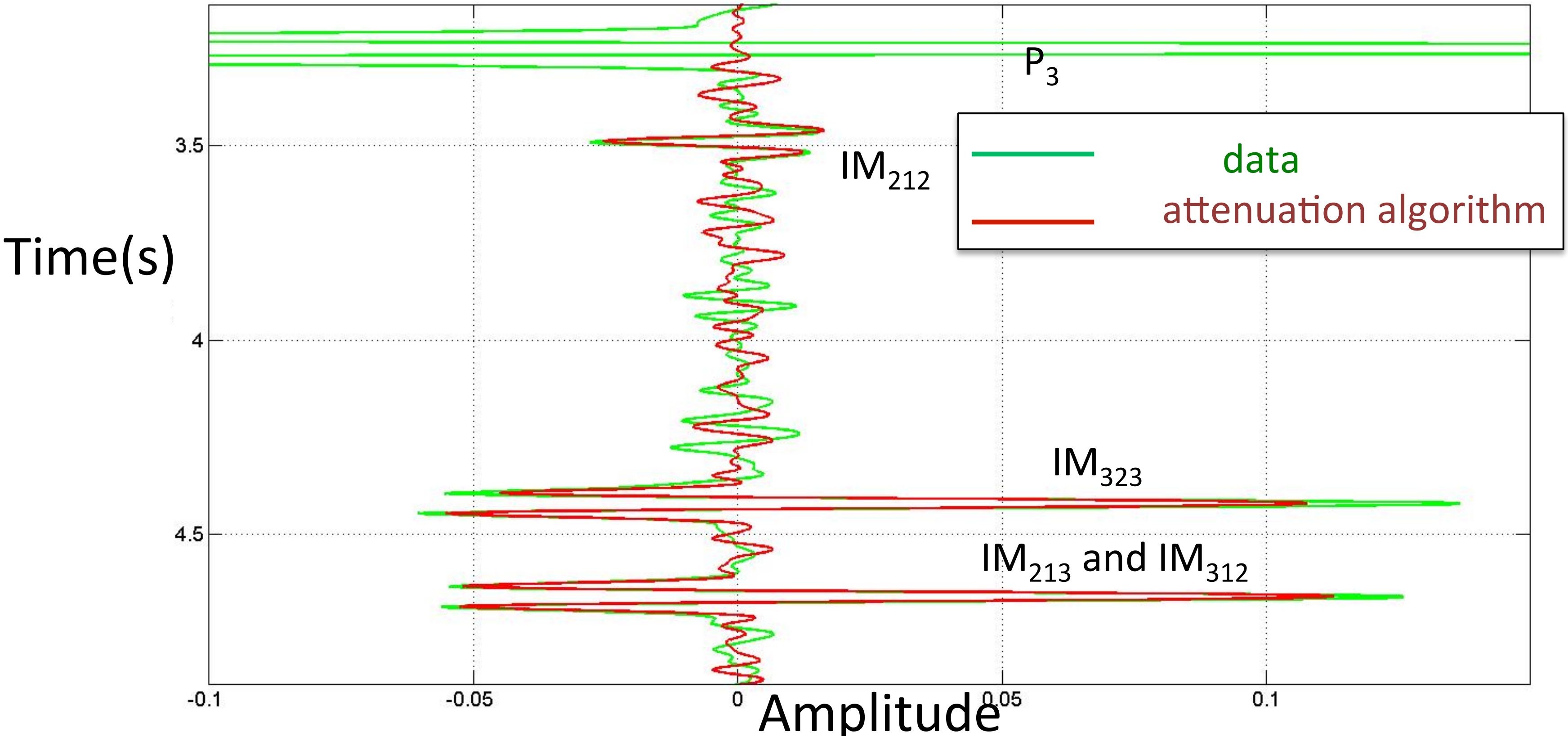
ISS internal multiple elimination

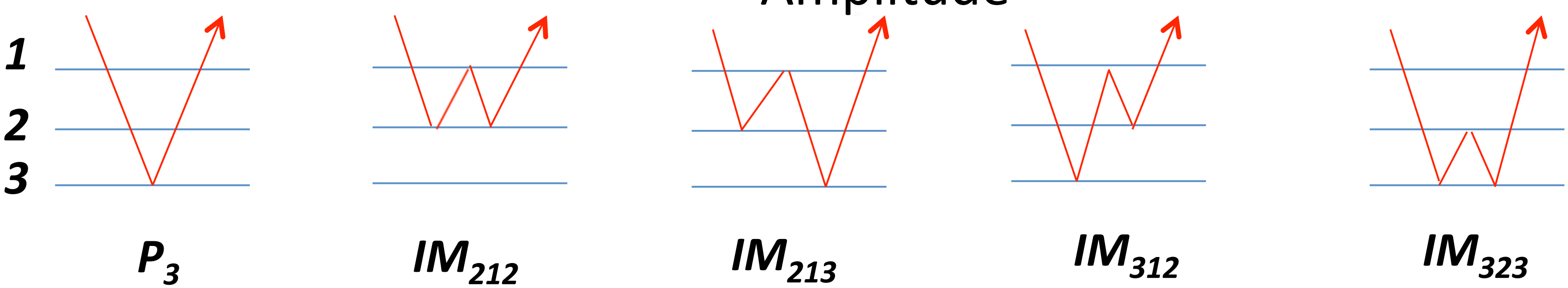
Test 1 — noise data

A. Test for perfect data.
B. Test for bandlimited data.
C. Test for data with white noise.

ISS internal multiple elimination

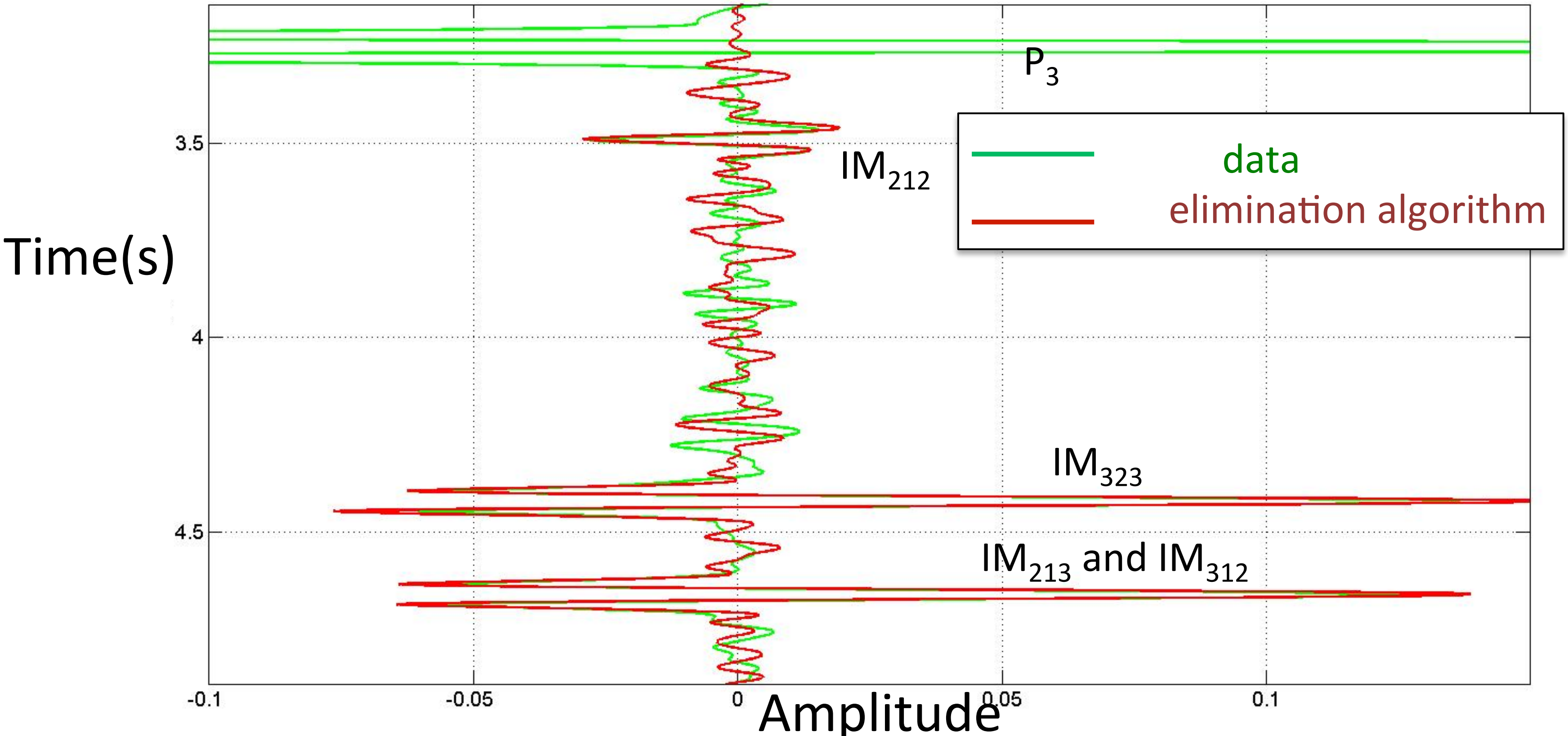
Test 1 — noise data, attenuation algorithm prediction

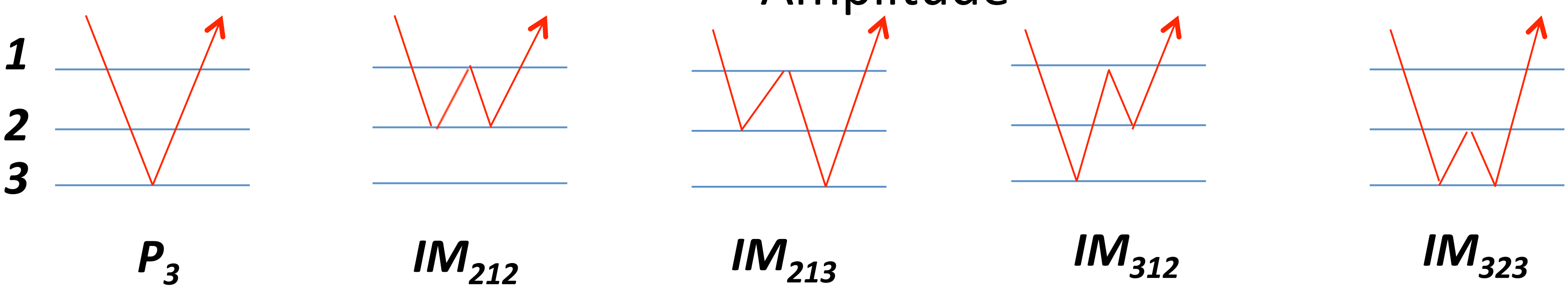




ISS internal multiple elimination

Test 1 — noise data, elimination algorithm prediction

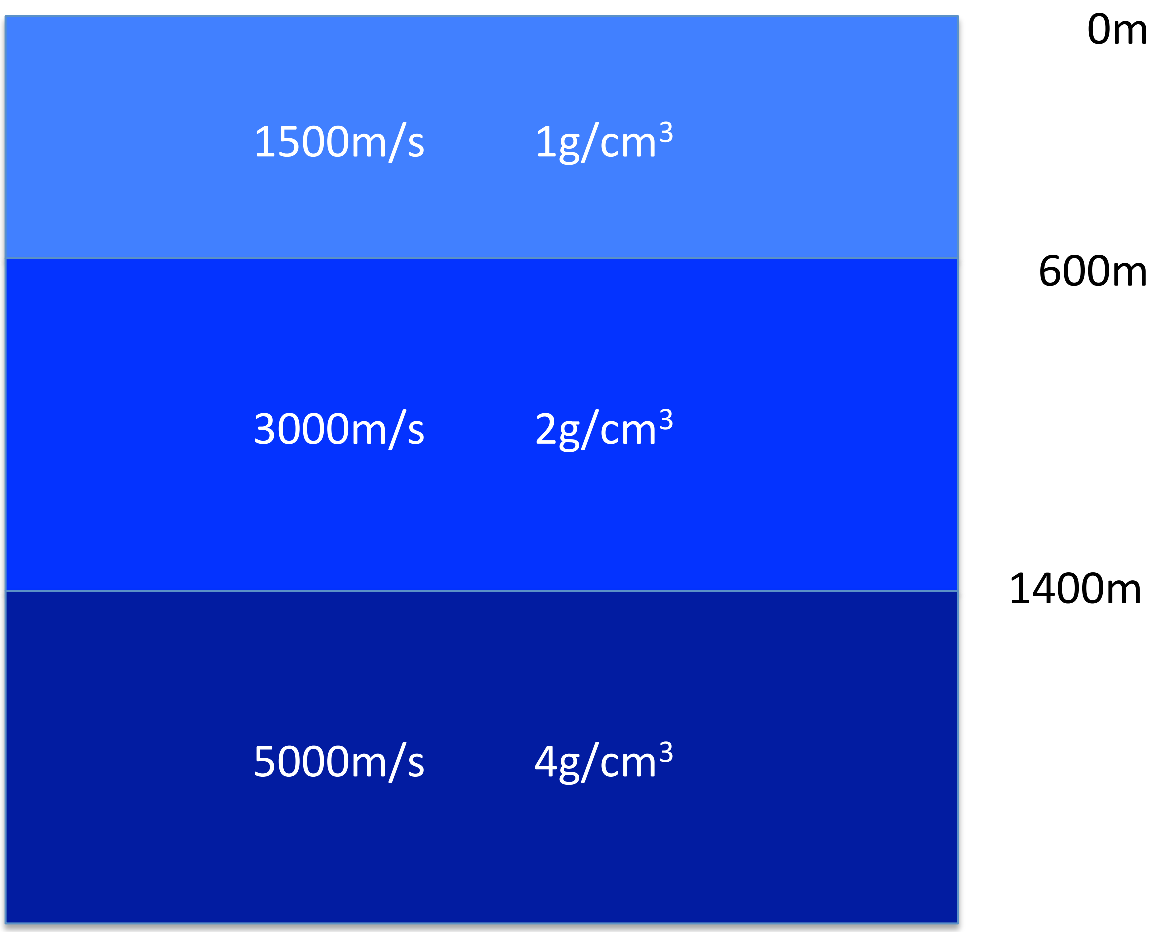




Test 2: 1D earth offset data for 2D sources & receivers

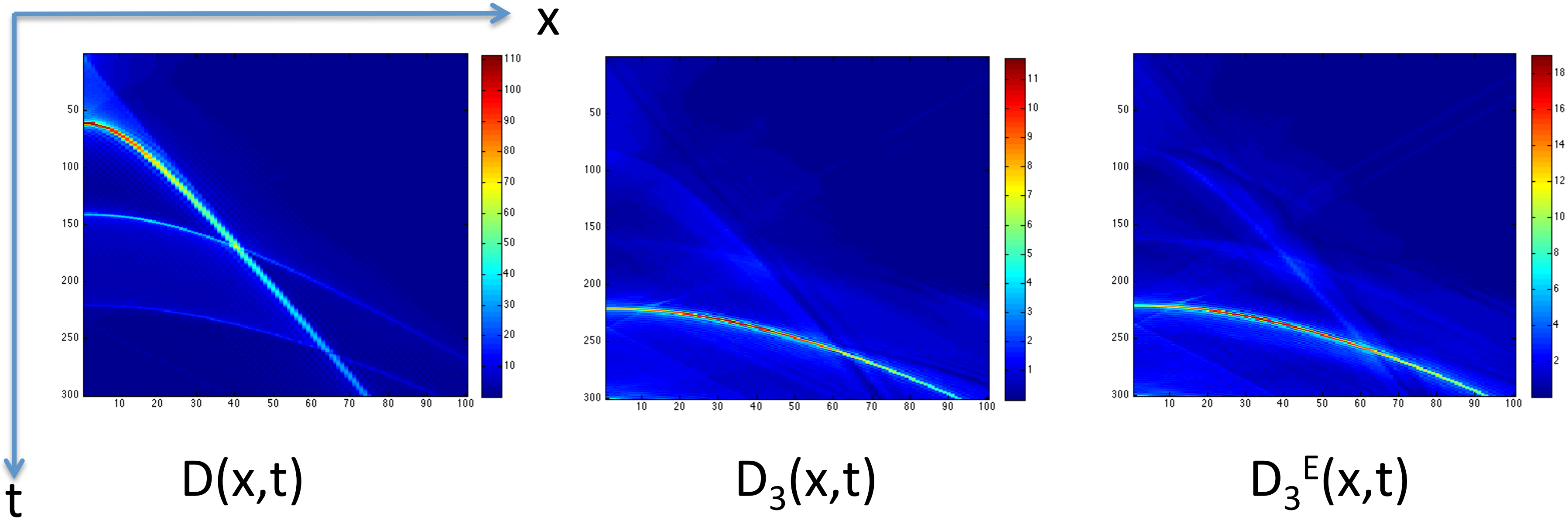
ISS internal multiple elimination

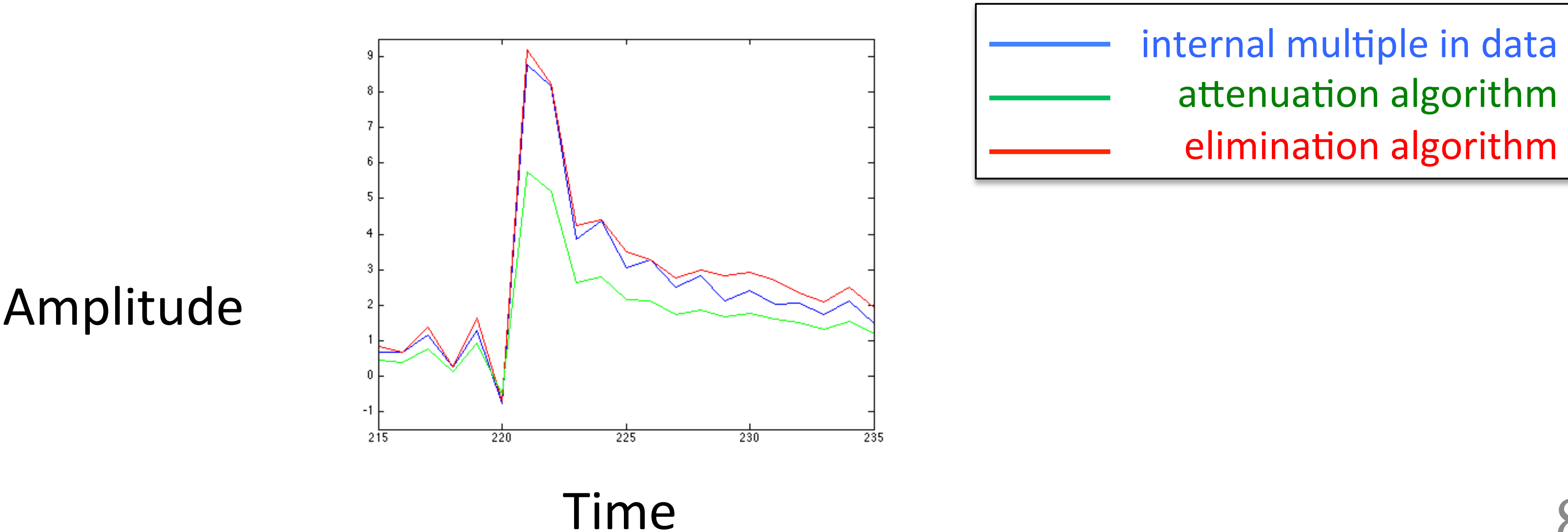
Test 2—model



ISS internal multiple elimination

Test 2 — offset = 0 m

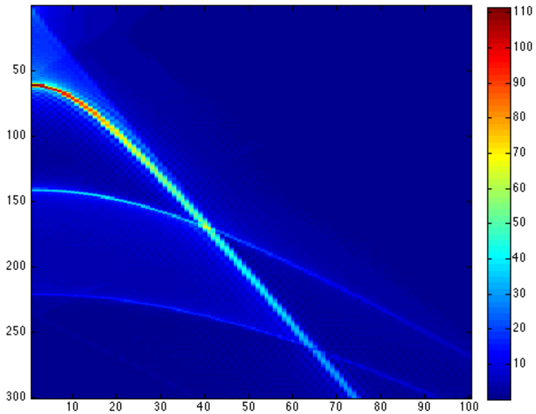




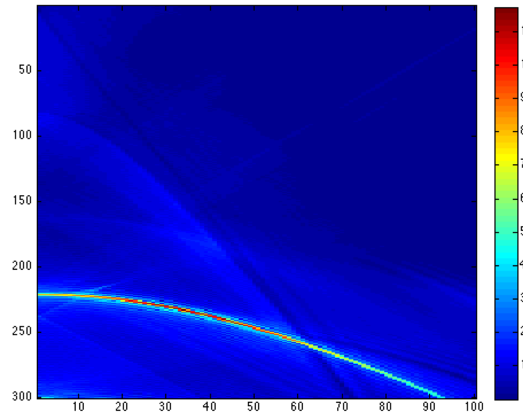
ISS internal multiple elimination

Test 2 — offset = 200 m

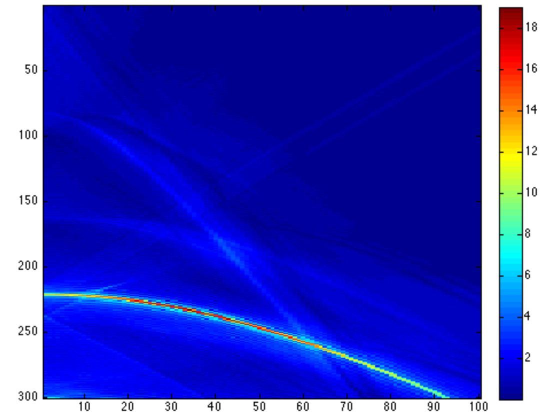
x



D(x,t)

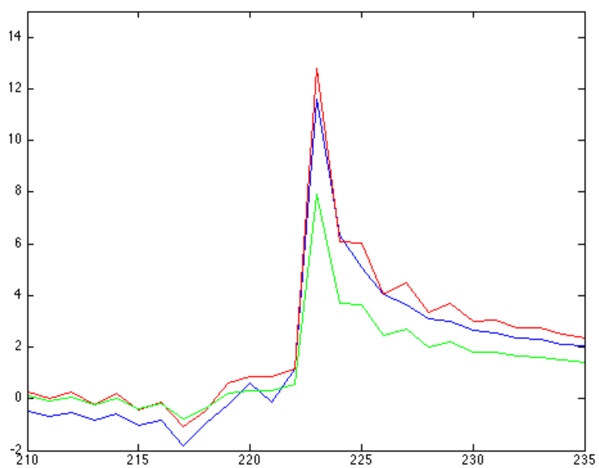


$D_3(x,t)$



$D_3^E(x,t)$

Amplitude

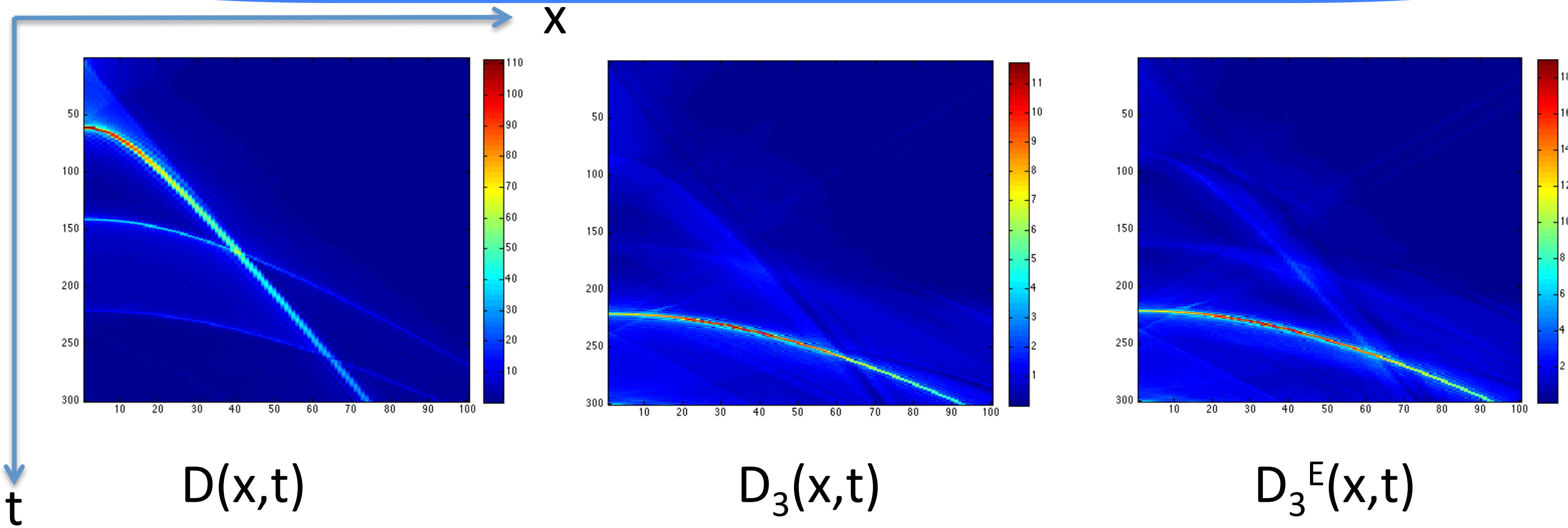


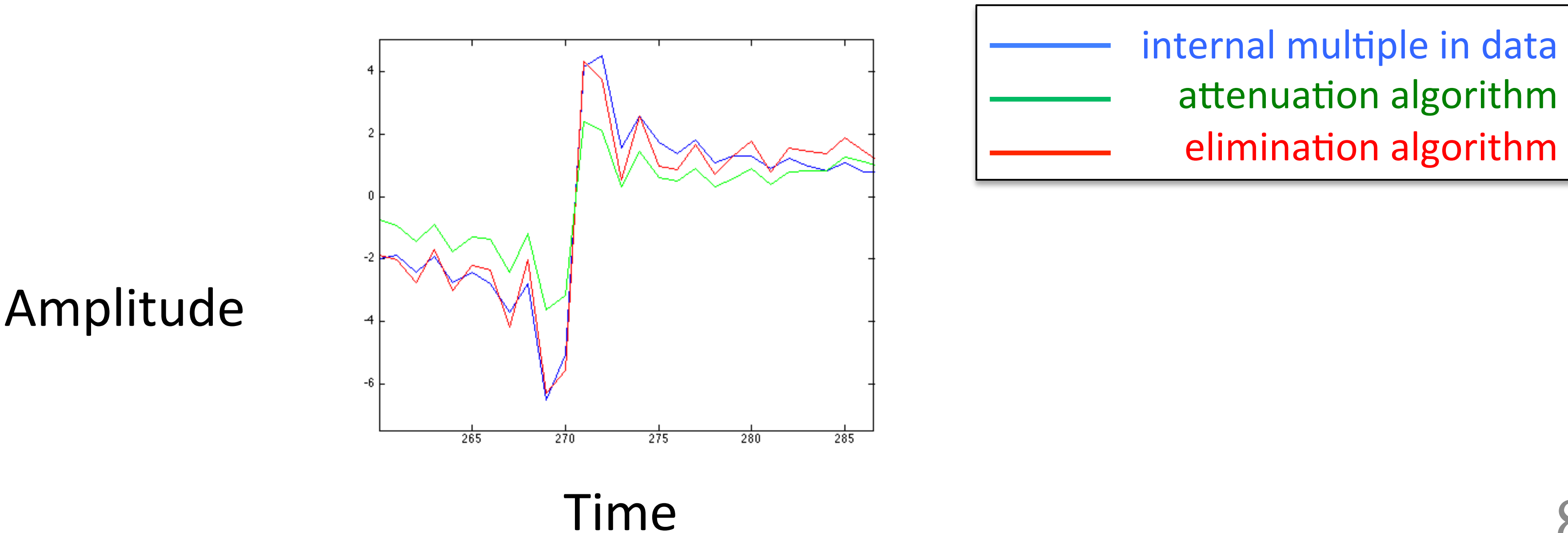
Time

internal multiple in data
attenuation algorithm
elimination algorithm

ISS internal multiple elimination

Test 2 — offset = 800 m





ISS internal multiple elimination

Flow chart of the elimination algorithm

Input: data $D(k,\omega)$

$$b_1(k,\omega) = -2iqD(k,\omega)$$

$$g(k,z) = \frac{1}{2\pi}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} dz'dq' \frac{e^{-iq'z}e^{iq'z'}b_1(k,z')}{1-\int_{-\infty}^{z'-\varepsilon}dz''b_1(k,z'')e^{iq'z''}\int_{z''-\varepsilon}^{z''+\varepsilon}dz'''g^*(k,z''')e^{-iq'z'''}}$$

$$F[b_1(k,z)] = \frac{1}{2\pi}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} dz'dq' \times$$

$$\frac{e^{-iq'z}e^{iq'z'}b_1(k,z')}{[1-\int_{-\infty}^{z'-\varepsilon}dz''b_1(k,z'')e^{iq'z''}\int_{z''-\varepsilon}^{z''+\varepsilon}dz'''g^*(k,z''')e^{-iq'z'''}]^2[1-\int_{z'-\varepsilon}^{z'+\varepsilon}dz''g(k,z'')e^{iq'z''}\int_{z''-\varepsilon}^{z''+\varepsilon}dz'''g^*(k,z''')e^{-iq'z'''}]}$$

$$b_E^{IM}(k,2q) = \int_{-\infty}^{\infty} dz e^{2iqz} b_1(k,z)\int_{-\infty}^{z-\varepsilon_1} dz' e^{-2iqz'} F[b_1(k,z')]\int_{z'+\varepsilon_2}^{\infty} dz'' e^{2iqz''} b_1(k,z'')$$

Output: internal multiples with correct time and amplitude $b_E^{IM}(k,2q)$

ISS internal multiple elimination

A limitation that will be addressed in part 2

The primaries in data b_1	→	Provide the elimination capability
The internal multiples in data b_1	→	will diminish the elimination capability

ISS internal multiple elimination

A limitation that will be addressed in part 2

The primaries in data b_1 → Provide the elimination capability

The internal multiples in data b_1 → will diminish the elimination capability

It is the limitation of this **elimination** algorithm.
This limitation will be addressed in part 2.

ISS internal multiple elimination

discussion and future plan

Towards internal multiple elimination: where are we now? what are our next steps? when can you anticipate being able to use this algorithm?

- Current elimination algorithm is for an acoustic 1D earth for 2D sources & receivers.
- Develop elimination algorithm for an acoustic 1D earth for 3D point sources & receivers.
- Test the 3D point source 1D earth acoustic algorithm for an elastic model. If it shows added value, then we will test it on field data where the earth is close to 1D. If successful, we will distribute a documented code to sponsors.
- Develop a 3D elimination algorithm directly from terms in the inverse scattering series.

M-OSRP

Misson - Oriented Seismic Research Program

Solve The Right Problem

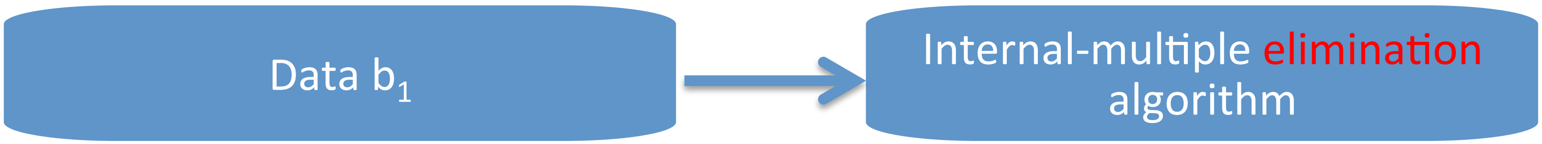
The internal-multiple *elimination* algorithm for all reflectors for 1D earth
Part 2: addressing the limitations

Yanglei Zou* and Arthur B. Weglein

May 29th, 2014

Austin, TX

Addressing the limitation of the current **elimination** algorithm



Addressing the limitation of the current **elimination** algorithm

Data b_1 → Internal-multiple elimination algorithm

The primaries in data b_1 → Provide the elimination capability

The internal multiples in data b_1 → will diminish the elimination capability

Addressing the limitation of the current **elimination** algorithm

Data b_1 → Internal-multiple elimination algorithm

The primaries in data b_1 → Provide the elimination capability

The internal multiples in data b_1 → will diminish the elimination capability

It is the limitation of this **elimination** algorithm.

This limitation will be addressed in part 2.

Addressing the limitation of the current **elimination** algorithm

$$b'_1 = b_1 + b_3$$

benefit from Chao Ma, et al (2012) Hong Liang, et al (2012)

Addressing the limitation of the current **elimination** algorithm

$$b'_1 = b_1 + b_3$$

benefit from Chao Ma, et al (2012) Hong Liang, et al (2012)

To Address the limitation of the **elimination** algorithm, we use b'_1 instead of using b_1 as the input data for the ISS internal multiple elimination algorithm

Addressing the limitation of the current **elimination** algorithm

current elimination algorithm

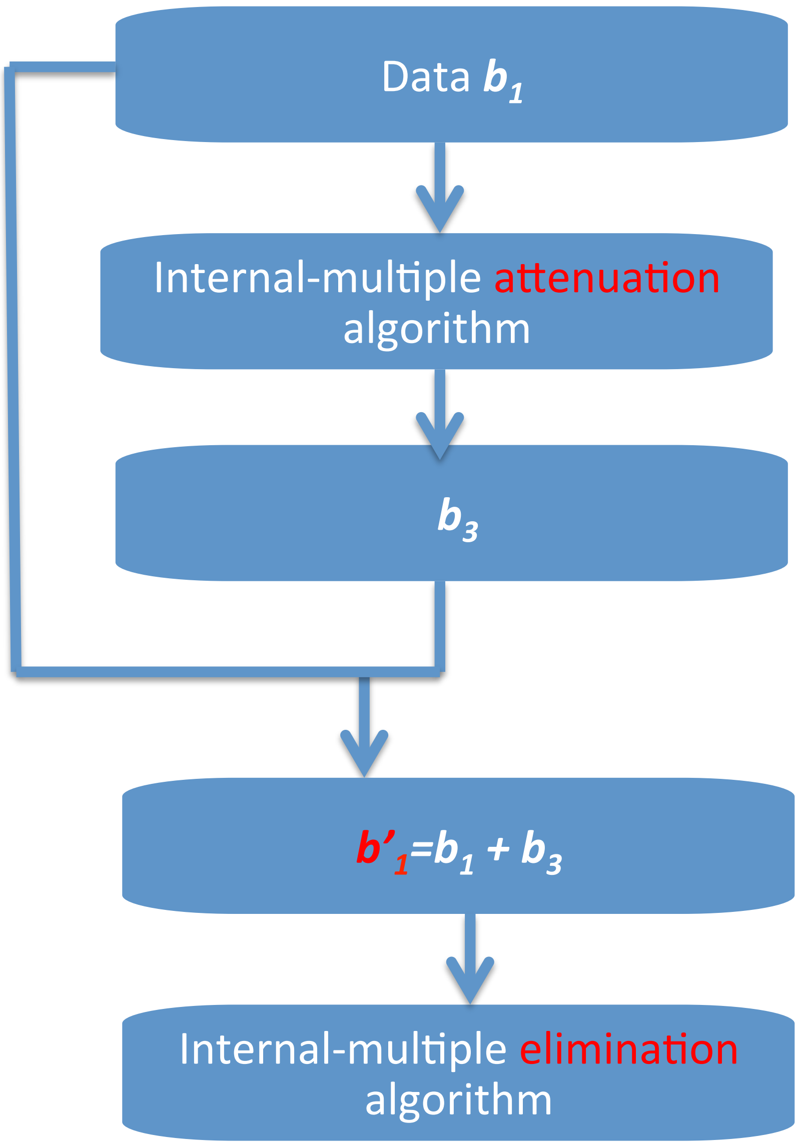
Data $\boldsymbol{b_1}$

↓

Internal-multiple elimination algorithm

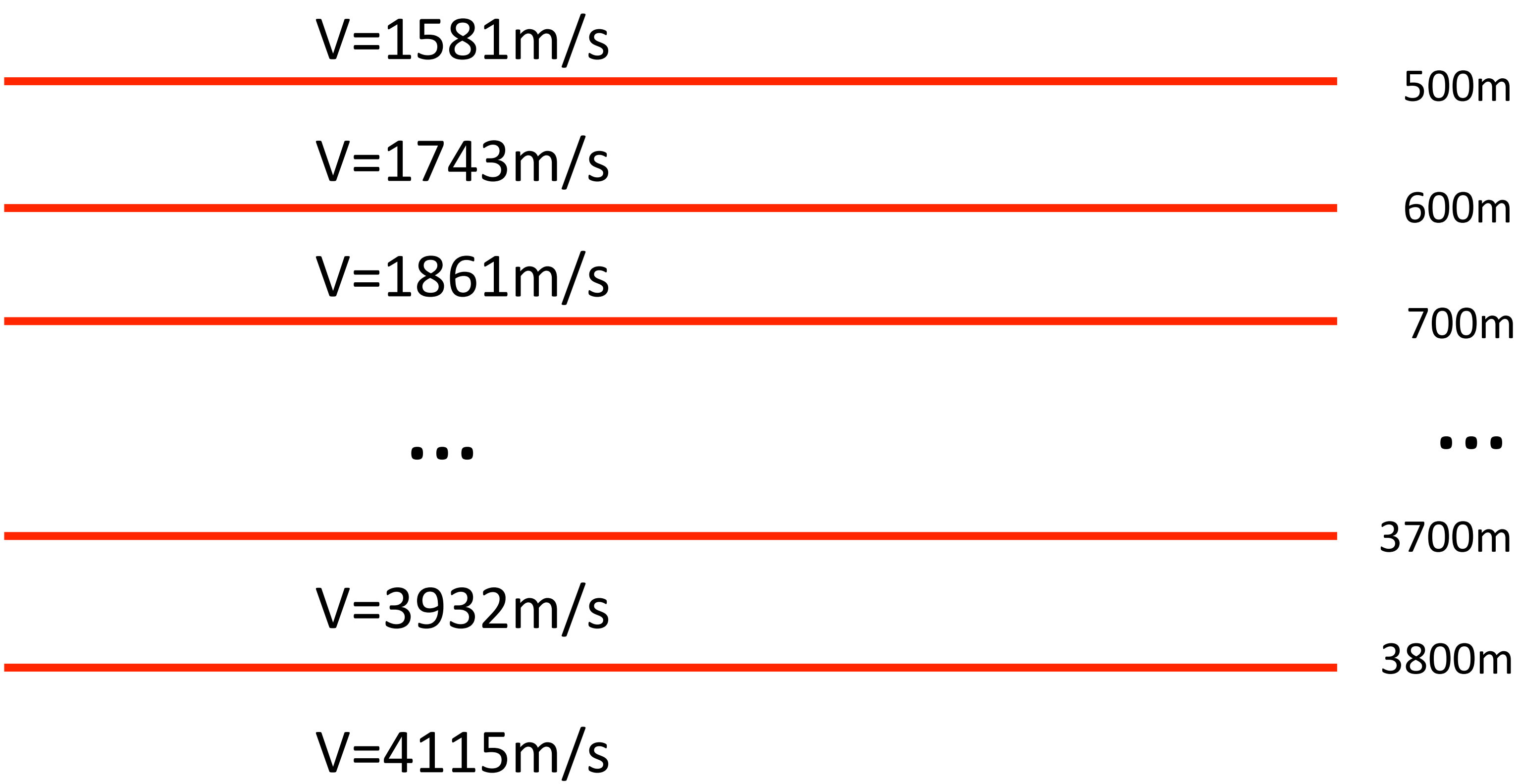
Addressing the limitation of the current **elimination** algorithm

modified strategy for the elimination algorithm



1D normal incidence numerical test based on well log velocity data

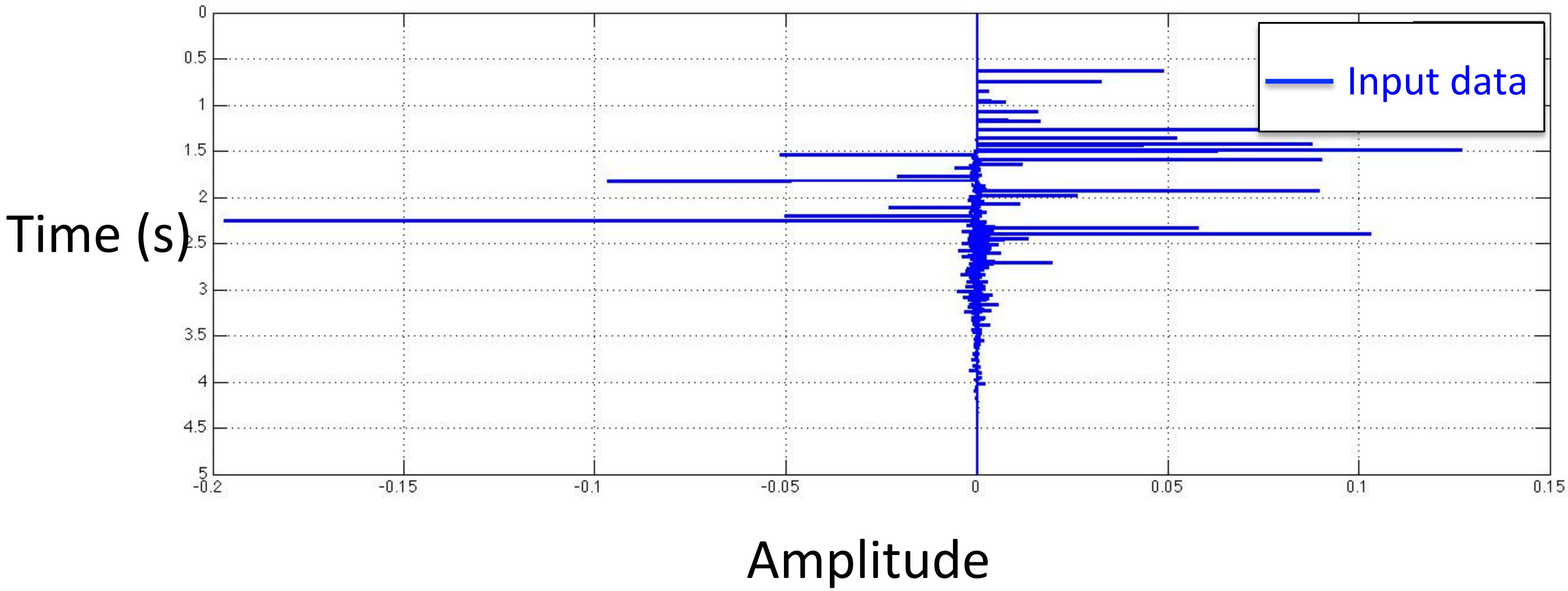
34-reflector model based on well log velocity data



(courtesy of Saudi Aramco)

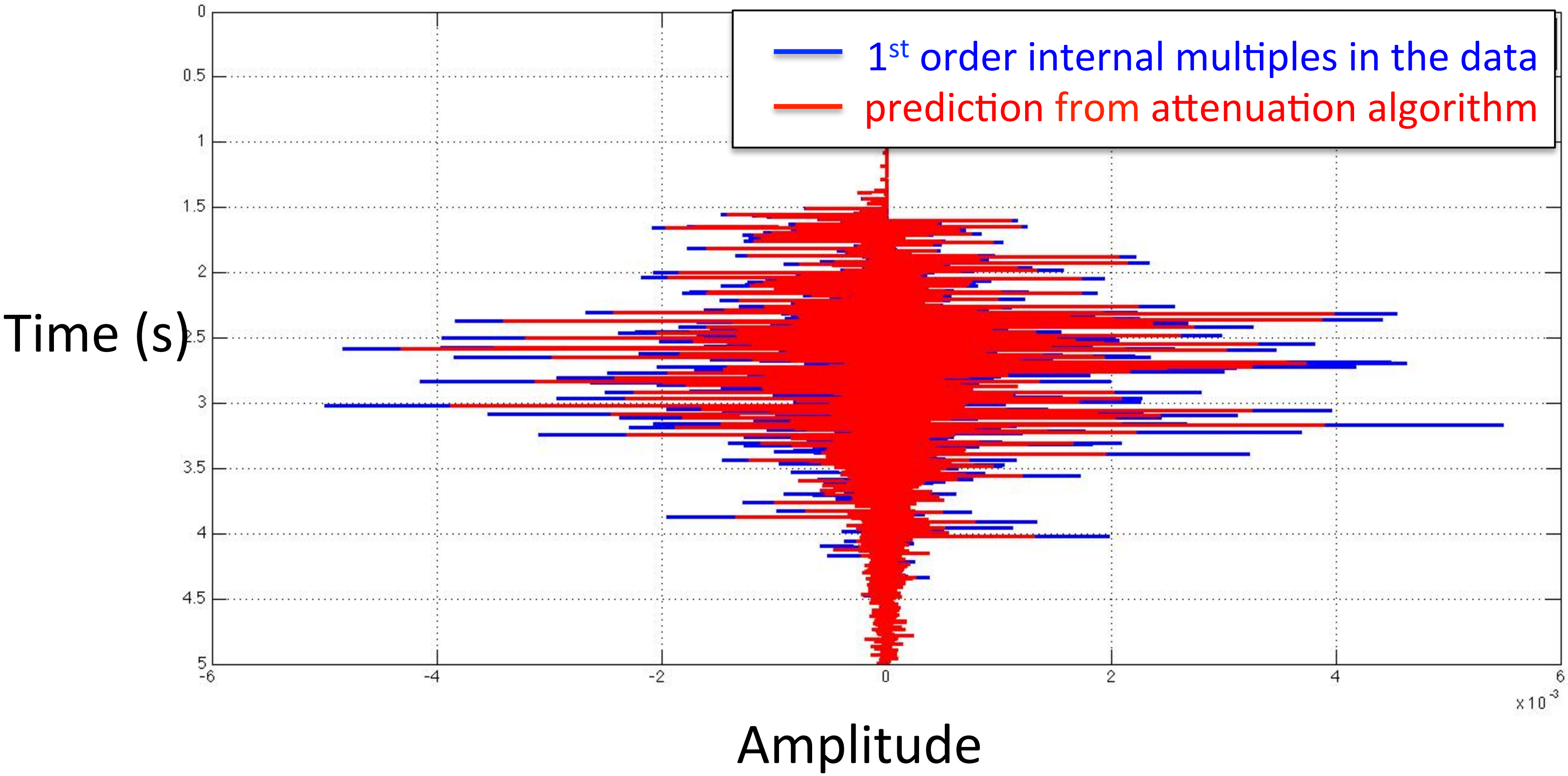
Addressing the limitation of the current **elimination** algorithm

Numerical test—input data



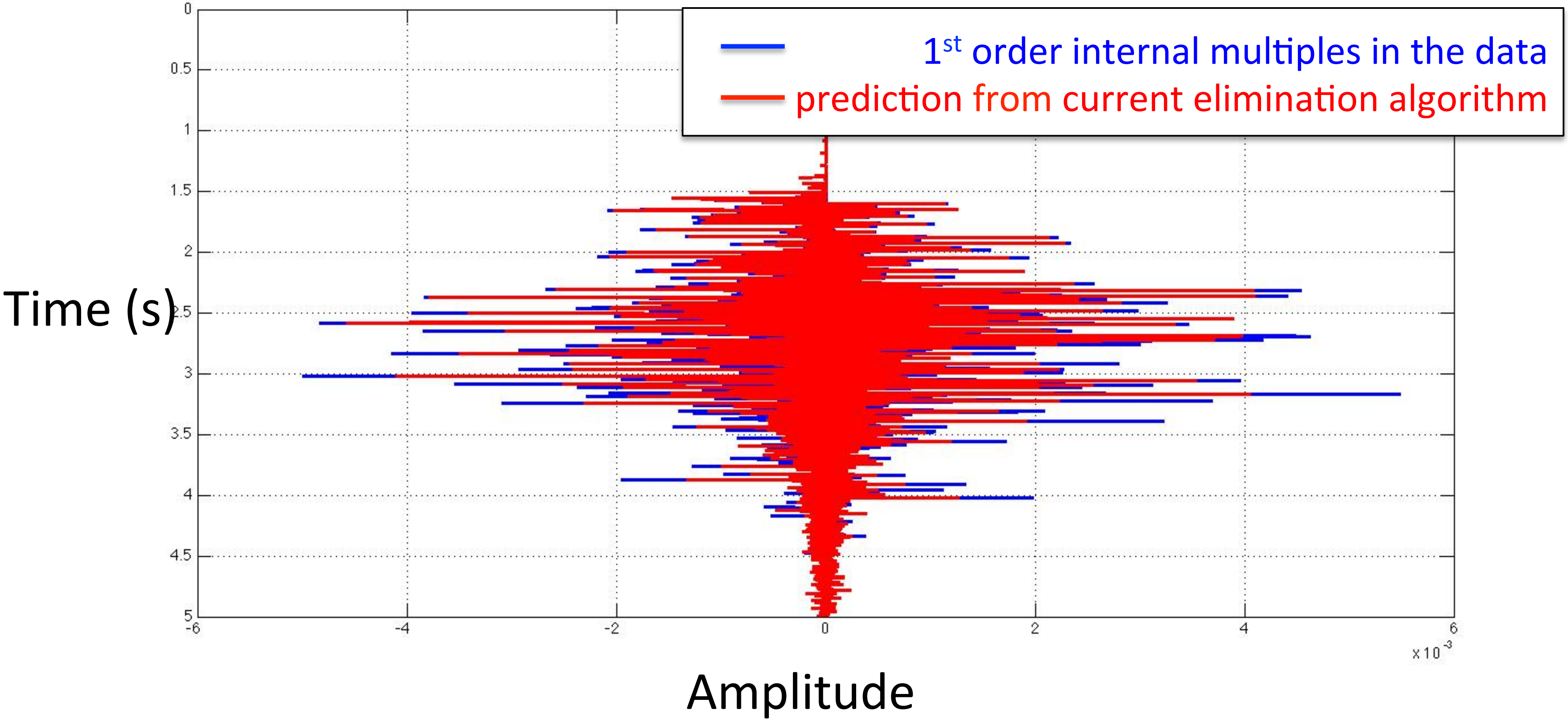
Addressing the limitation of the current **elimination** algorithm

Numerical test — prediction from attenuation algorithm



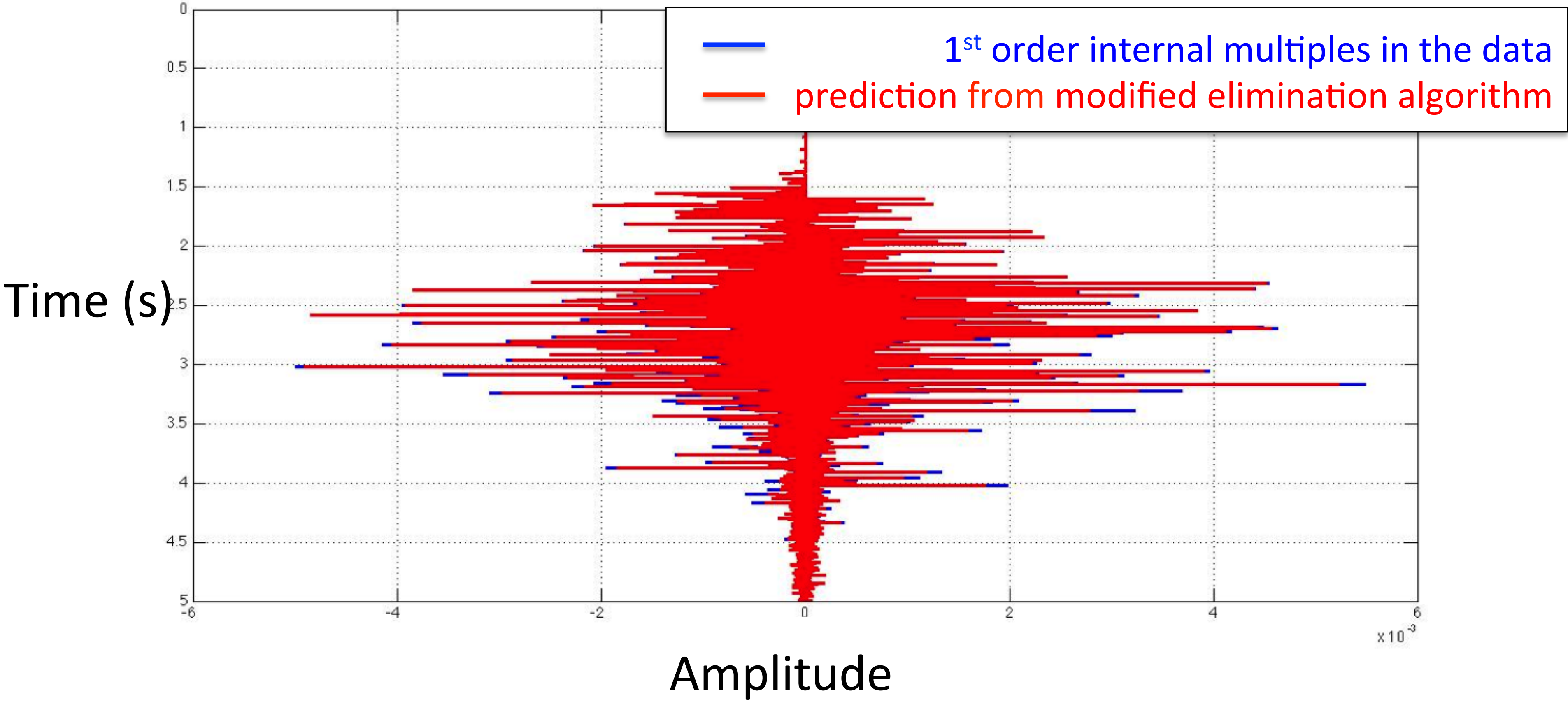
Addressing the limitation of the current **elimination** algorithm

Numerical test — prediction from current **elimination** algorithm



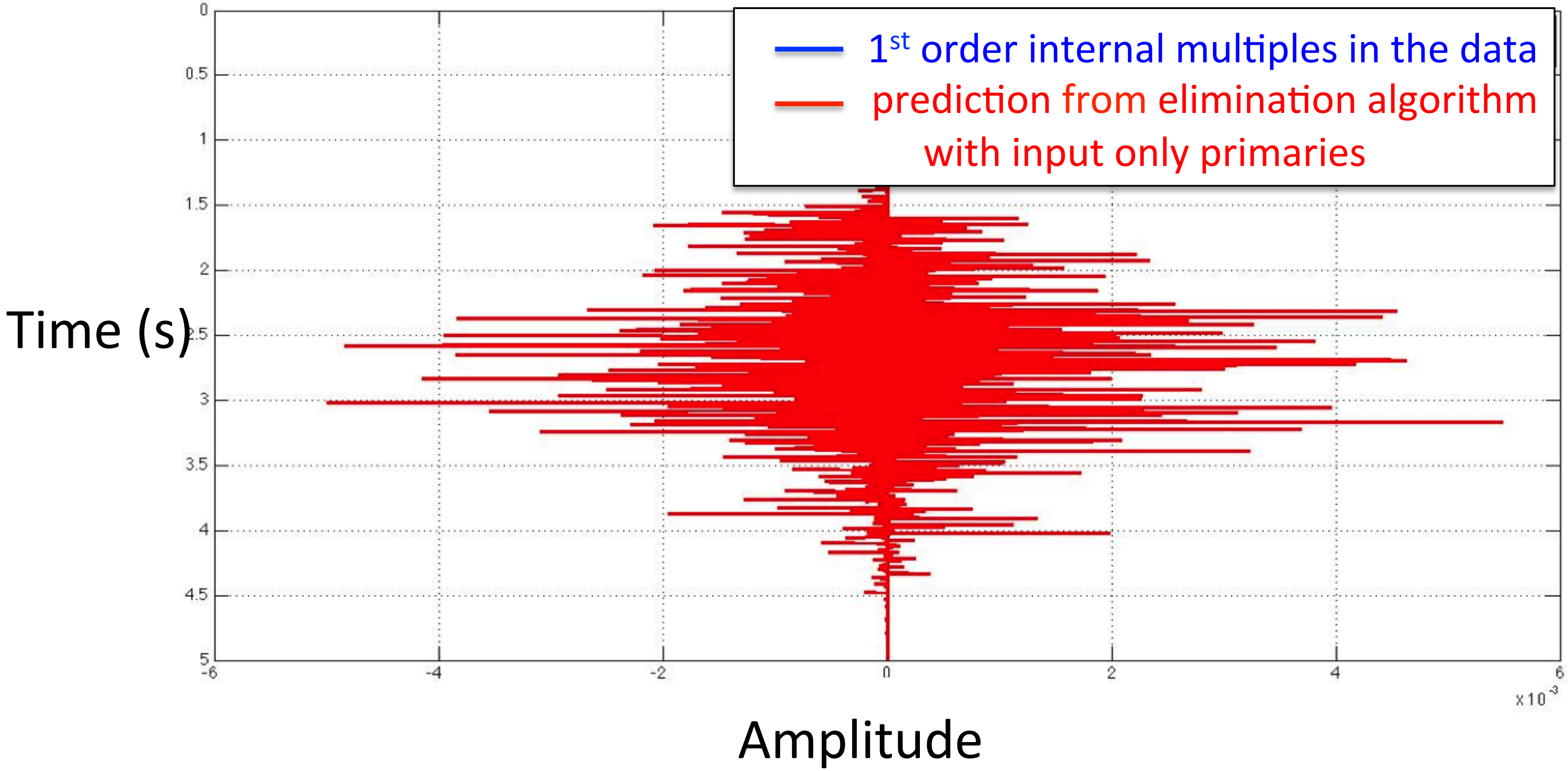
Addressing the limitation of the current **elimination** algorithm

Numerical test — prediction from modified **elimination** algorithm



Addressing the limitation of the current **elimination** algorithm

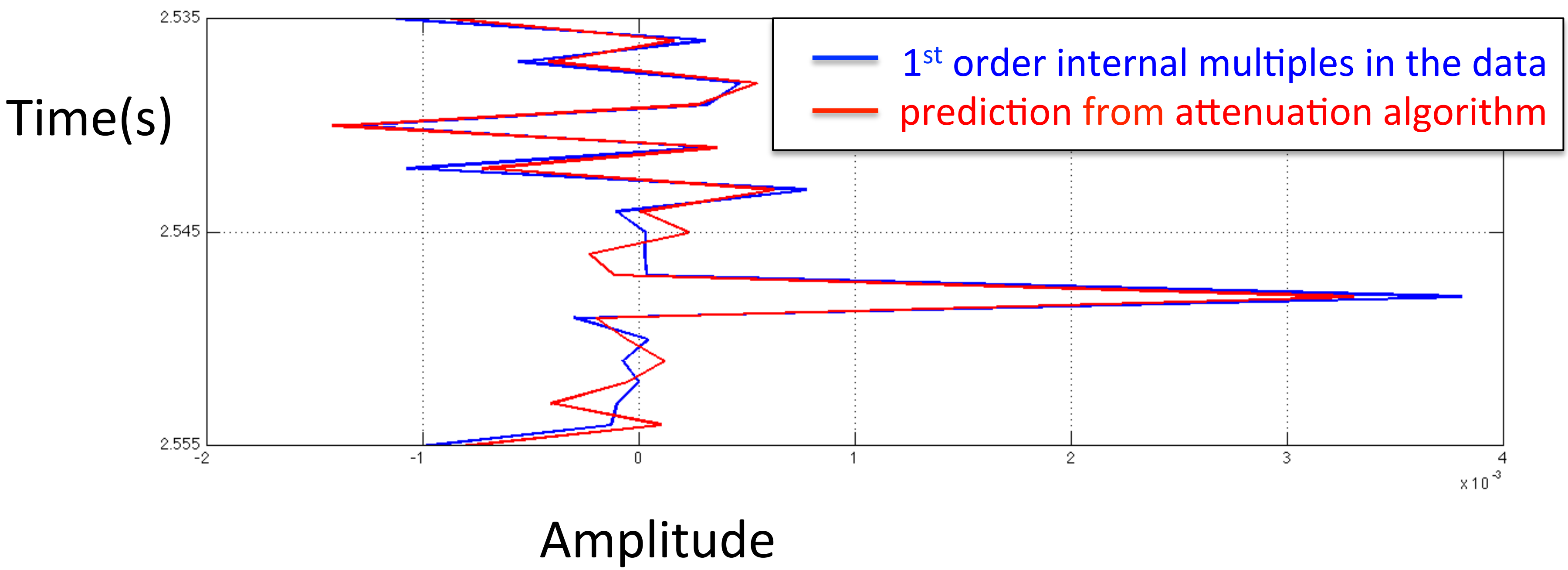
Numerical test—prediction from current **elimination** algorithm with input only primaries



Addressing the limitation of the current **elimination** algorithm

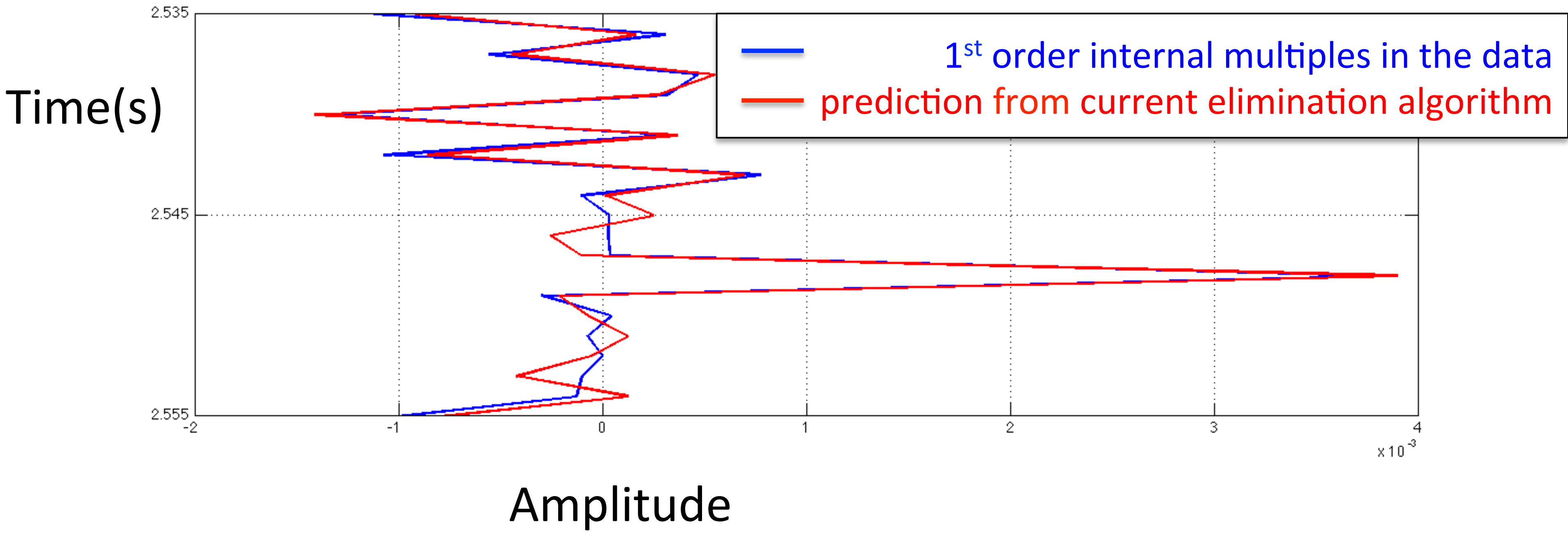
Numerical test—prediction from attenuation algorithm

(Blow up)



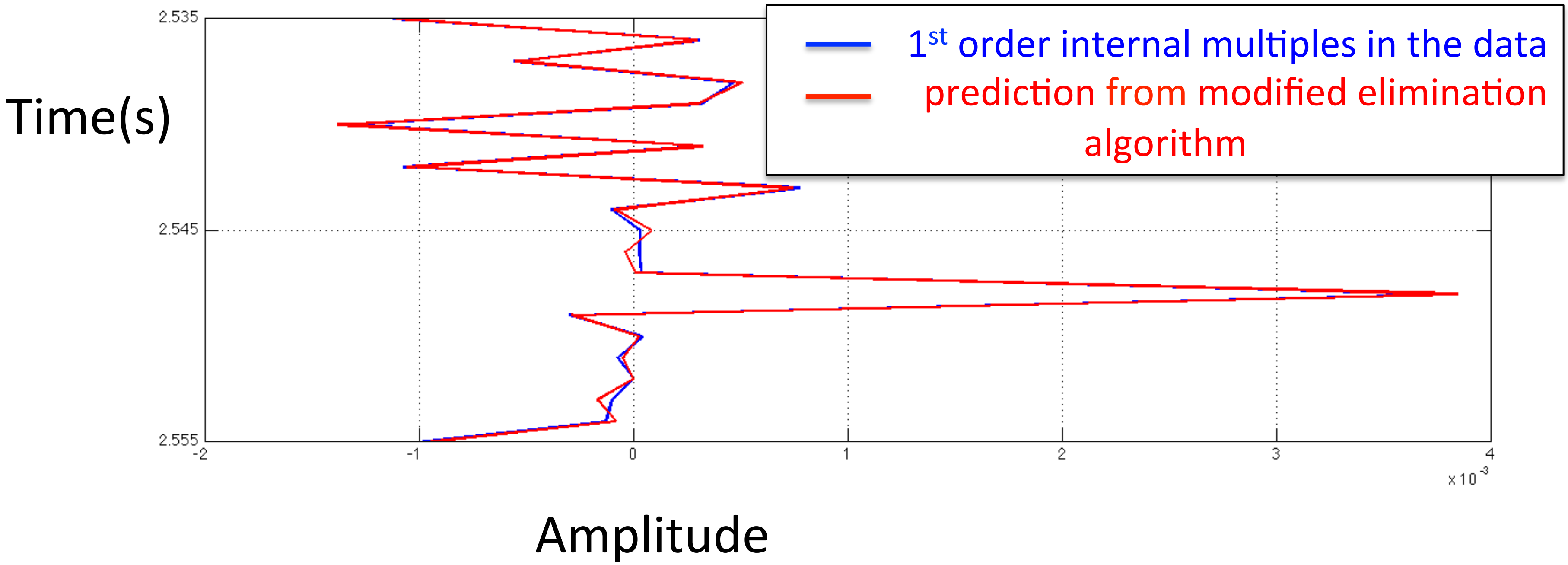
Addressing the limitation of the current **elimination** algorithm

Numerical test—prediction from current **elimination** algorithm (Blow up)



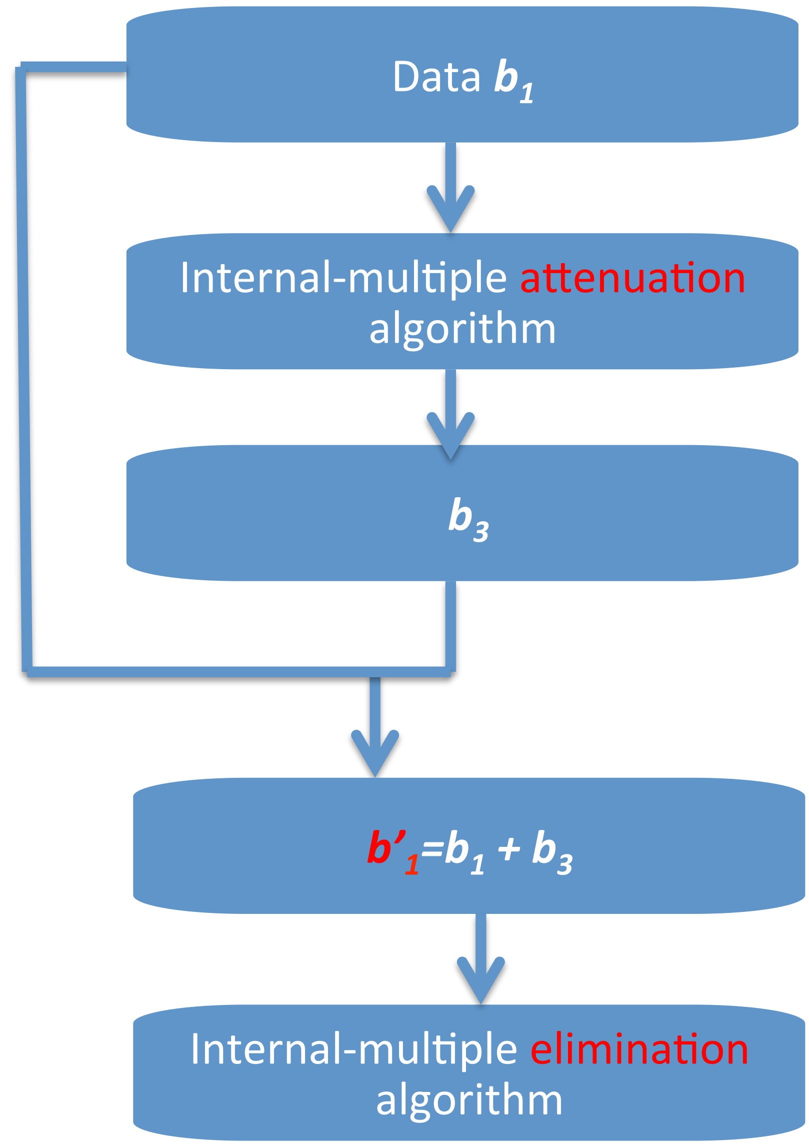
Addressing the limitation of the current **elimination** algorithm

Numerical test—prediction from modified **elimination** algorithm (Blow up)



Addressing the limitation of the current **elimination** algorithm

the ISS internal multiple **elimination** algorithm with the limitation being addressed



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M-OSRP

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