Enhanced Response Error Correction (ERC)

Background:

I'm seeking advice using **enhanced response forwards error correction** for a university project. The project involves taking raw S11 and S21 measurements with a HP8753 two port analyser and learning to apply error correction.

We've successfully achieved 1 port error correction for reflection measurements but having no luck with transmission measurements.

Last post I made, Dr Joel suggested I buy his book "Handbook of Microwave Component Measurements" which I did, and has proved to be a very informative and useful book.

To convey my question easily, I've adopted his style of notation.

Basically, we cannot get the equations for enhanced response correction to work. Upon further investigation, I cannot see how they possibly could.

We developed our own equations based on our own observations that work successfully with a range of loads, however I am perplexed as to why the equations published in several HP documents don't appear to work.

I've detailed the equations, procedures and results below and I'm hoping someone can shed some light on the situation.

Thanks in advance,
Josh

Procedure that we use:

Step1.
Turn correction OFF!
Perform 1 port SOL calibration to measure and calculate the following errors:
Directivity: **EDF** (measured directly from S11 with 50R load)
Source Match: **ESF** and Reflection Tracking: **ERF**
(ESF and ERF are calculated from precise Short and Open models for best accuracy. The models are basically the measured results of each standard from the fully calibrated HP8753 using the 85032B cal kit.)

Step2.
Connect 50R to both ports and measure Crosstalk: **EXF** directly from S21

Step3.
Connect both ports together with a flush through and measure Transmission Tracking: **ETF** directly from S21.

Results:

Reflection measurements are corrected as per the standards 1 port error model:

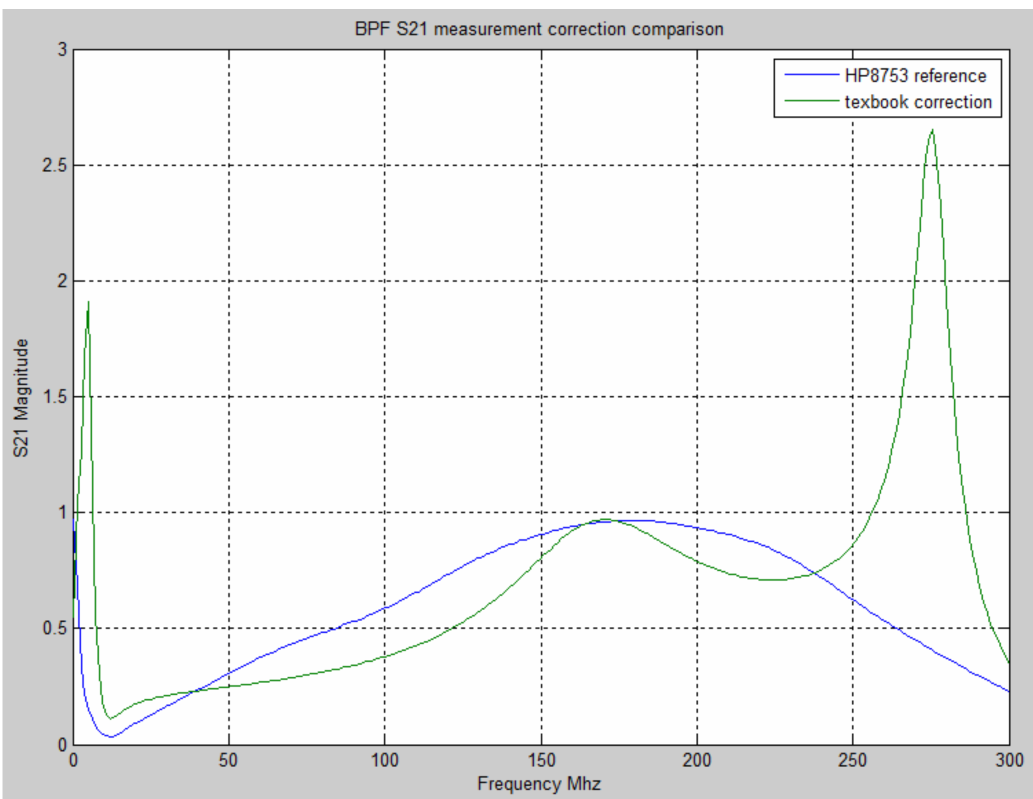
$$S11A = \frac{(S11M - EDF)}{[ERF + (S11M - EDF).ESF]}$$

We get very good correlation to the HP8753 with correction ON, which leads us to believe that we have good models for our calibration standards, and that we've measured, calculated and applied the errors correctly.

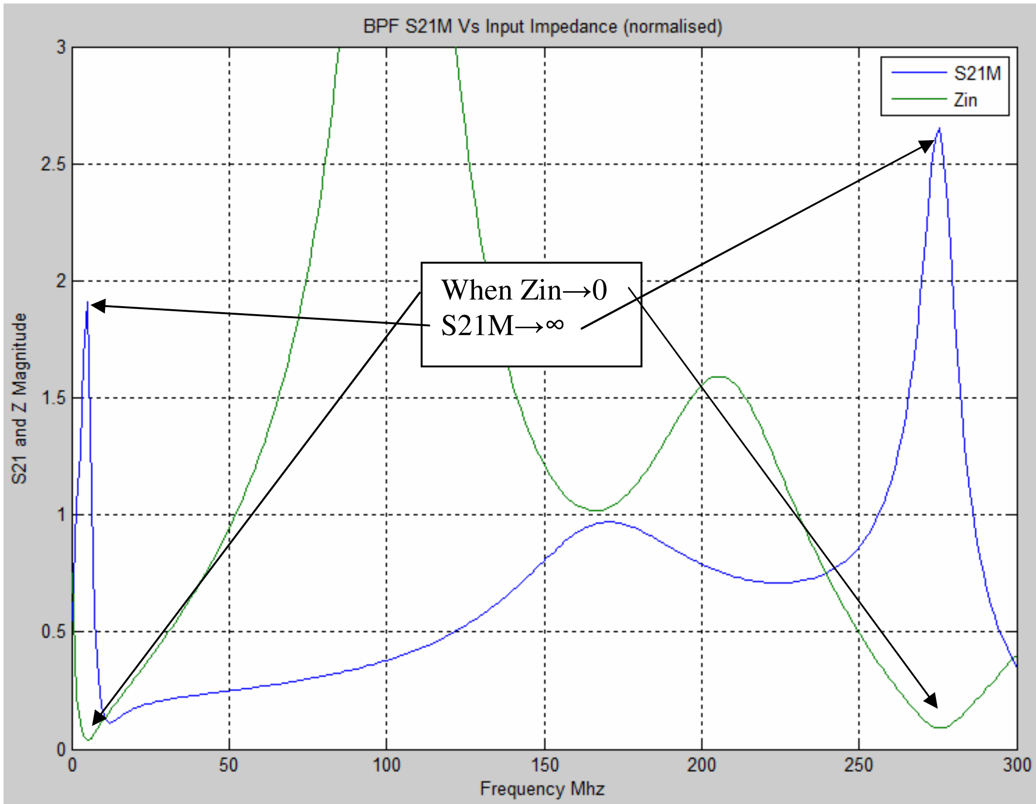
The equation for enhanced response correction (ERC) is given in numerous publications -in one form or another- as:

$$S21A = \frac{(S21M - EXF)}{ETF.\left(1 + \frac{(S11M - EDF)}{ERF}.ESF\right)}$$

Our application of this formula on our raw results yields very poor correlation to the HP8753 corrected measurements. It's OK for a resistive attenuator that presents a 50R input impedance across the frequency range but a BPF that presents a very poor port match yields terrible results:



At frequencies where the input impedance of the BPF approaches a short, the magnitude of the S21 result goes well above 2!



Looking closer at the ERC equation, I'm perplexed at how it could work.
I've rearranged it to illustrate my point:

$$S21A = \left(\frac{S21M - EXF}{ETF}\right) / \left(1 + \frac{(S11M - EDF)}{ERF}.ESF\right)$$

≈0

This part makes sense:
Remove the crosstalk EXF and normalise to the through response ETF.

This part doesn't:
If the analyser has a good source match ESF≈0.
This negates the second term, so S11M has no effect?

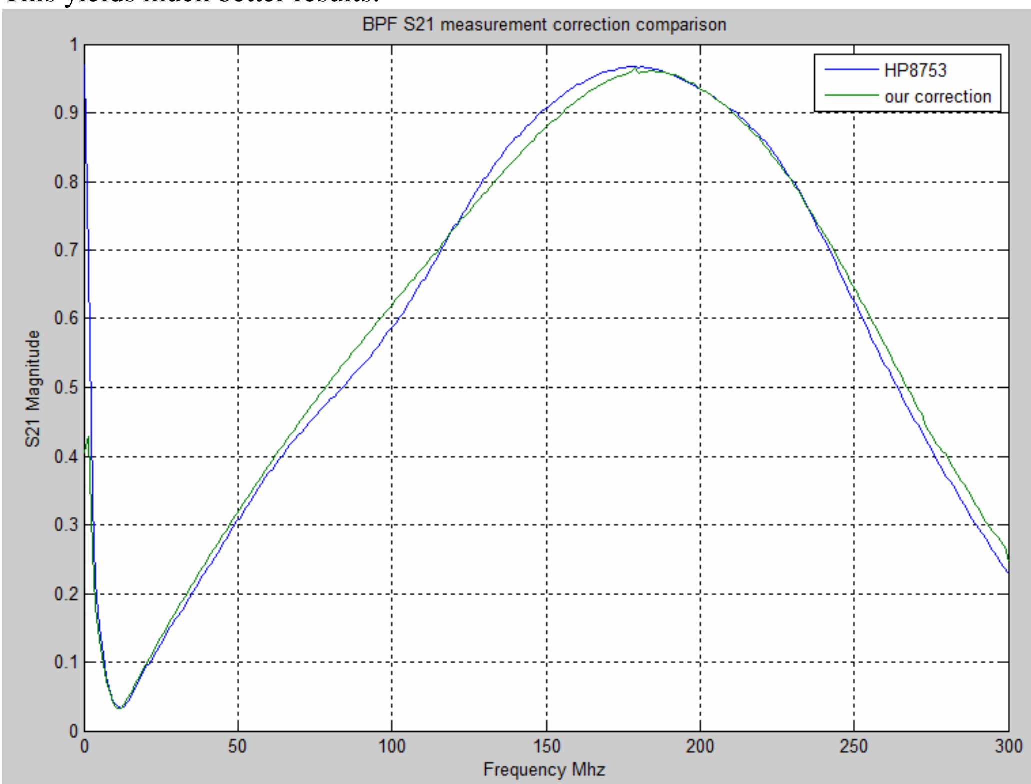
Realising that it was the input impedance of the BPF causing the spikes in the S21 results, we came up with our own simple but effective equation:

$$S21A = \left(\frac{S21M - EXF}{ETF} \right) * \left(1 + S11M \right)$$

Same normalised through response.

As input impedance approaches a short, S11M→-1 . So this term approaches 0 reducing the spikes in the S21 results.

This yields much better results:



So the question is:

Have we miss understood the ERC equation, or its application?