RBSP-EFW-TN039
Estimation of System Voltage Gain from Laboratory Measurements and Impact On Thermal F_UH Detection

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The end-to-end voltage gain of the RBSP EFW-to-EMFISIS E-Field I/F can be separated into three component parts:

1. A voltage divider ahead of the unity-gain follower consisting of the effective sheath impedance, any series impedance between the sensor input and follower input, and the effective input impedance of the unity-gain follower itself.
2. The voltage divider formed by the effective output impedance of the unity-gain follower, effective cable impedance when connected to the BEB, and effective load impedance presented by the BEB, EMFISIS E-field I/F, and DFB first circuits.
3. The voltage transfer function (frequency response) of the EMFISIS E-Field buffer itself.

While the effect of (1) seems well modeled by lumped passive circuit elements, and the effect of (3) is also well-understood, the impact of (2) is not (at least by Bonnell…), based on comparison between simple one-pole models of the roll-off frequency of the cable, for example. Thus, working with the measured end-to-end voltage gains is called for.

JWB would like to acknowledge Ludlam, Hochman, Irwin, Dalen, Dalton, and Hoberman for significant extra effort over the past few weeks to accomplish the modifications to and testing of the ETU PRE units required by this effort.

Since discussions between JRW and JWB in late Nov 2009, analysis of measured voltage gains and the lumped circuit model for end-to-end voltage gain has pointed out some errors in the analytical model for frequency response of the EFW system, leading to the CBE voltage gain at 400-KHz being less than 0.1 for expected on-orbit sheath parameters:

1. The rolloff frequency for the post-follower voltage divider formed by the effective follower output resistance and cable capacitance was a factor of ~2 lower than predicted. This is probably due to both a larger effective follower output resistance (R2 plus OP-15 output impedance, rather than just the effect of R2), as well as a larger effective cable capacitance to ground due to coupling between the VSPHERE signal line, the other 6 singles in the custom cable, and the grounded outer braid.
2. The "ESD bypass capacitor," C_E, had a significantly attenuated the voltage gain in the 100- to 400-kHz band as well.

Based on these observations, the following actions were taken:

1. C_E was removed from one of the spare ETU SPB PRE boards; the modified PRE PWB was then installed to the ETU SPB and IDPU; the frequency response and stability were measured, and the response at 400-kHz was found to improve somewhat, to ~0.1.
2. C_E was removed from the second spare ETU SPB PRE board, and the value of series output resistor, R2, changed from 100 ohm, to 50 ohm, and then 25 ohm; the modified PRE PWB was then installed to the ETU SPB and IDPU (BEB only, or full IDPU, depending upon availability); the frequency response and stability were measured, and the response at 400-kHz was again found to improve, up to a |Gv| at 400-kHz of 0.19 for the R2=25 ohm case.

In order to transform the measured end-to-end voltage gains into the expected on-orbit end-to-end voltage gains, one has to estimate the values of the pre-follower circuit elements, as well as the stray impedances (capacitances) present at the sensor input node in the test configuration.

For the purposes of estimating the frequency response in the critical 100- to 400-kHz regime, the capacitive coupling regime is the relevant one.

Consider the voltage gain in the capacitive coupling regime in the grounded and driven F-BOX configurations (note that Ce has been deleted from this model):

- G (grounded) = Gg = Cs/(Cs + Ci + Cb)
- G (driven) = Gd = (Cs + Cb)/(Cs + Ci + Cb)

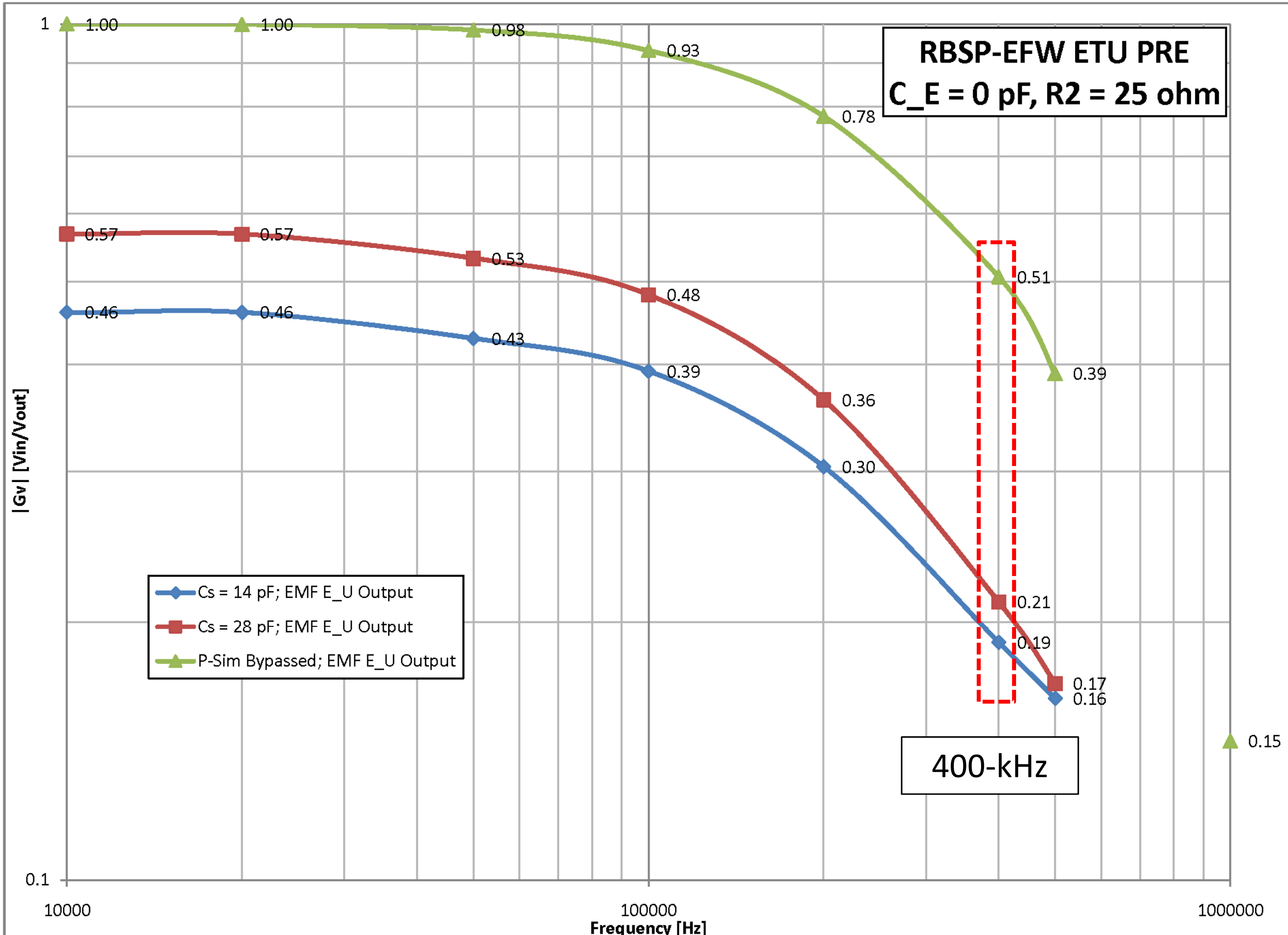
Do some algebra to extract the box and input capacitances in terms of the sheath capacitance (P-SIM capacitance):

- Cb/Cs = (Gd/Gg) – 1
- Ci/Cs = (1 – Gd)/Gg

One has to remove the effect of the post-follower and EMF buffer transfer functions from the measured end-to-end voltage gains before trying to estimate the pre-follower capacitances.

This is done by taking the measured voltage gain in the grounded and driven F-BOX configurations with the P-SIM in series with the sensor input and dividing by the measured voltage gain with the P-SIM bypassed (F-BOX config is irrelevant).

The final results of this analysis for the (C_E = 0 pF, R2 = 25 ohm), case are shown in the following slide, for the cases of Cs = 14 and 28 pF, and P-SIM bypassed, corresponding to the low-, mid-, and high-density plasma regimes on orbit.


RBSP-EFW ETU PRE
C_E = 0 pF, R2 = 25 ohm
400-kHz
Cs = 14 pF; EMF E_U Output
Cs = 28 pF; EMF E_U Output
P-Sim Bypassed; EMF E_U Output
1.00
1.00
0.98
0.93
0.78
0.51
0.39
0.15
0.57
0.57
0.53
0.48
0.36
0.21
0.17
0.46
0.46
0.43
0.39
0.30
0.19
0.16
1
0.1
|Gv| [Vin/Vout]
10000
100000
1000000
Frequency [Hz]

The next slide shows the nominal thermal upper hybrid emission spectral densities (1e-14 to 1e-15 V2/Hz), attenuated by the CBE voltage gain in the 100- to 400-kHz interval, plotted with the estimated noise floor in the EMFISIS HFR band based on measurements taken during the EFW-EMFISIS Playdate (Aug 2009) using ETU1 of both EFW and EMFISIS.

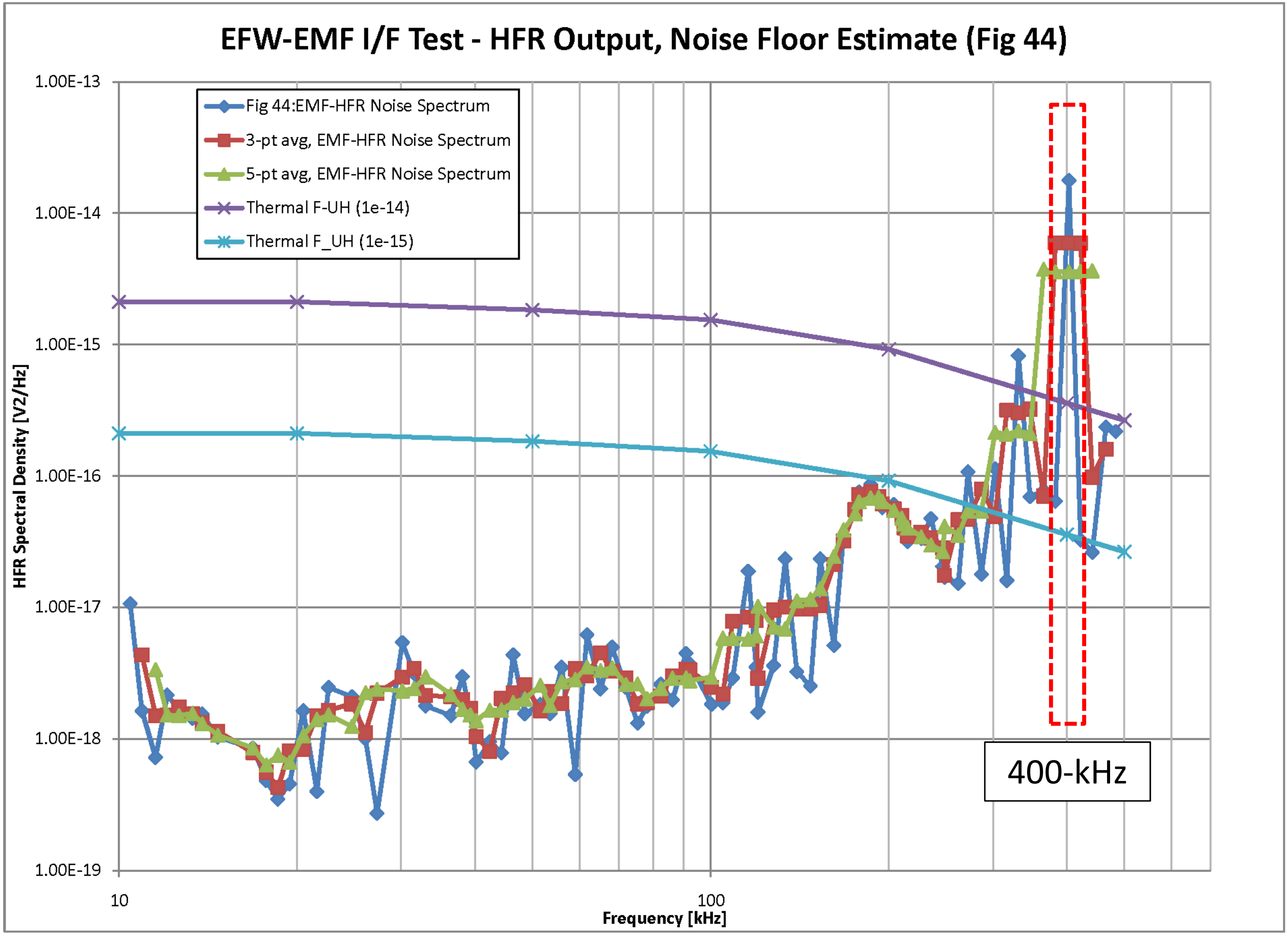
As can be seen, the signal-to-noise ratio (S/N) drops below 1 somewhere in the 300- to 400-KHz band, depending upon the expected amplitude of the F_UH emission (violet and light blue lines), and the level of smoothing used to estimate the continuum noise floor (medium blue, red, green for raw, 3-pt, and 5-pt smoothing).

The second subsequent slide shows model values of the f_UH emission frequency as a function of geocentric radial distance, along with the 300- to 400-kHz interval so that the impact of reduced S/N on region of operation can be discussed as needed.

Because of the low S/N in the relevant frequency band, further action to decrease the noise floor (direct improvement in S/N), and increase the EMFISIS buffer output signal amplitude in the 100- to 400-kHz band (to decrease succeptability to additional noise pick up on the EFW-EMFISIS E-Field interface) is warranted.

Subsequent actions to be taken:

1. Measurement of noise floor in HFR band using EFW IDPU ETU2 (LVPS ETU2; BEB ETU2). The expectation is that the contribution to the continuum noise floor from the EFW LVPS will decrease, but the amount of that decrease is unknown at this time (noise floor characterization on EMF E_U simulator, week of 14-18 Dec 2009).
2. Discussion and adjustment of EFW-EMFISIS E-Field buffer frequency response (15 Dec 2009).



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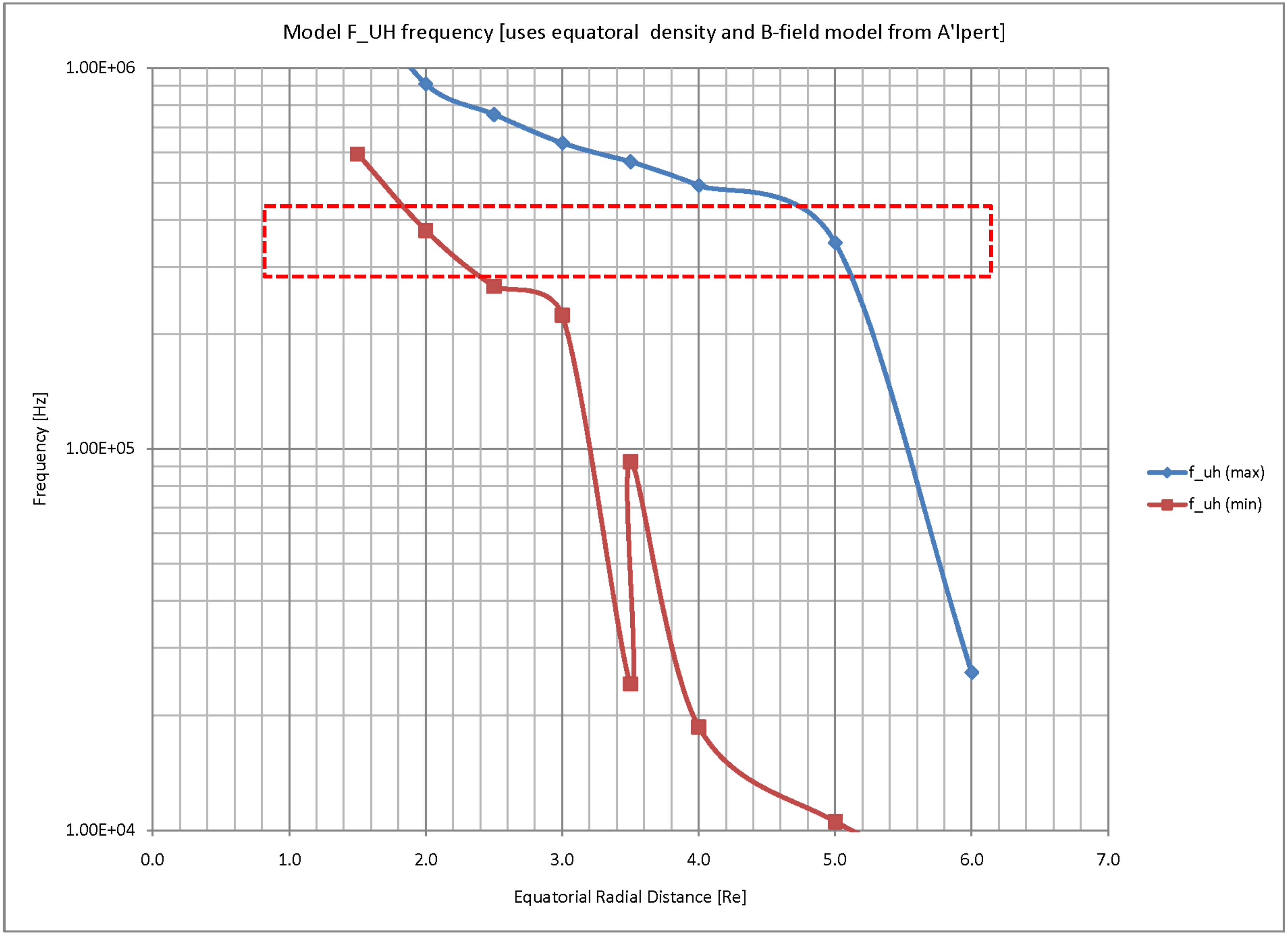
Model F_UH frequency [uses equatoral density and B-field model from A'lpert]
1.00E+06
1.00E+05
1.00E+04
Frequency [Hz]
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
Equatorial Radial Distance [Re]
f_uh (max)
f_uh (min)