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Subject: Sensitivity of EDGES Antenna Propotype to Different Perturbations

1 Description

It is necessary to quantify the effect of small physical changes in either the antenna or its surroundings, on the measured antenna reflection coefficient. For this purpose a series of tests was conducted.

In all cases the antenna was measured without balun shield. In its reference state, the antenna is orientated such that the panels connected to the balun are pointing due north and south respectively. This orientation produces the smoothest reflection coefficient with minimum influence of the surrounding walls, consistent with that obtained previously in a soccer field. Snap-on ferrites chokes were attached to the flexible coaxial cable every 1 m. The setup was calibrated at the end of the cable. Traces were saved with no averaging in order to obtain descriptive behavior on shorter time scales.

Every test starts with a measurement of the antenna in its reference state. For tests that required several changes or repetitions, a reference measurement was carried out before each of them. The tests conducted are:

1. *Deforming the antenna*: the balun was raised off the base by 1.5 mm.

2. *Tilting the antenna*: each corner of the plastic base was lifted by 1 inch so the antenna pivoted at the opposite corner. Since the diagonal of the base is 34 inches long, this corresponds to an angle of 1.7°. By lifting the corners rather than the sides of the base, the antenna is tilted along the N-S and E-W axes, given the reference position of the antenna.

3. *Rotating the antenna*: the antenna was rotated horizontally by 5° eastward and westward from its reference orientation.

4. *Lifting the antenna*: the antenna was raised 4 mm above the ground plane.

5. *Modifying ground plane*: a 1 m^2 metal panel was located 2 and 3 meters away from the center of the antenna, 1 inch above the existing ground plane. This was done north, south, east, and west of the antenna.

6. *Pulling the antenna*: the antenna was pulled $\sim$4 mm along the N-S and E-W axes using a plastic fishing line, several times.

The results are shown in the following plots.

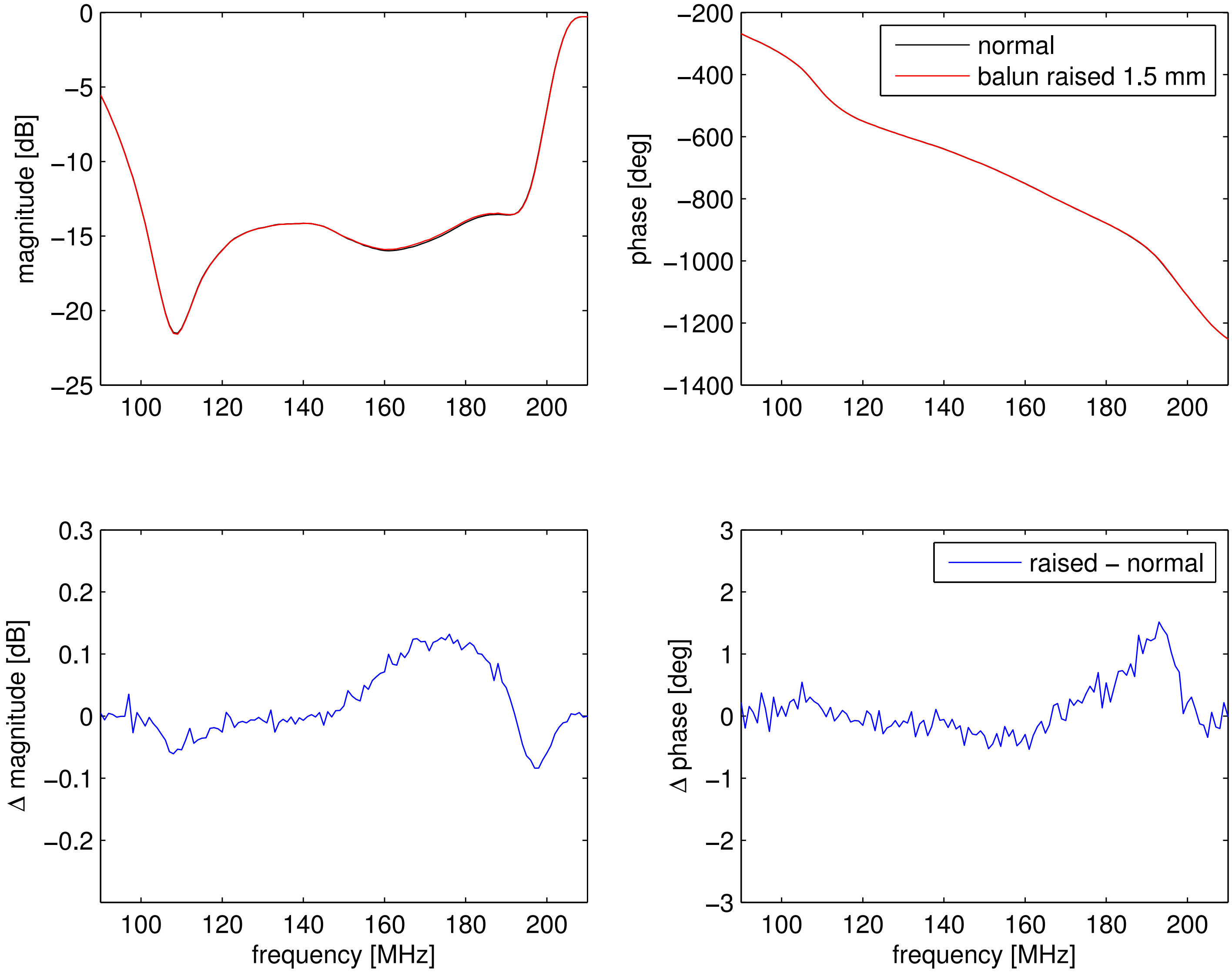

Figure 1: Deforming the antenna.

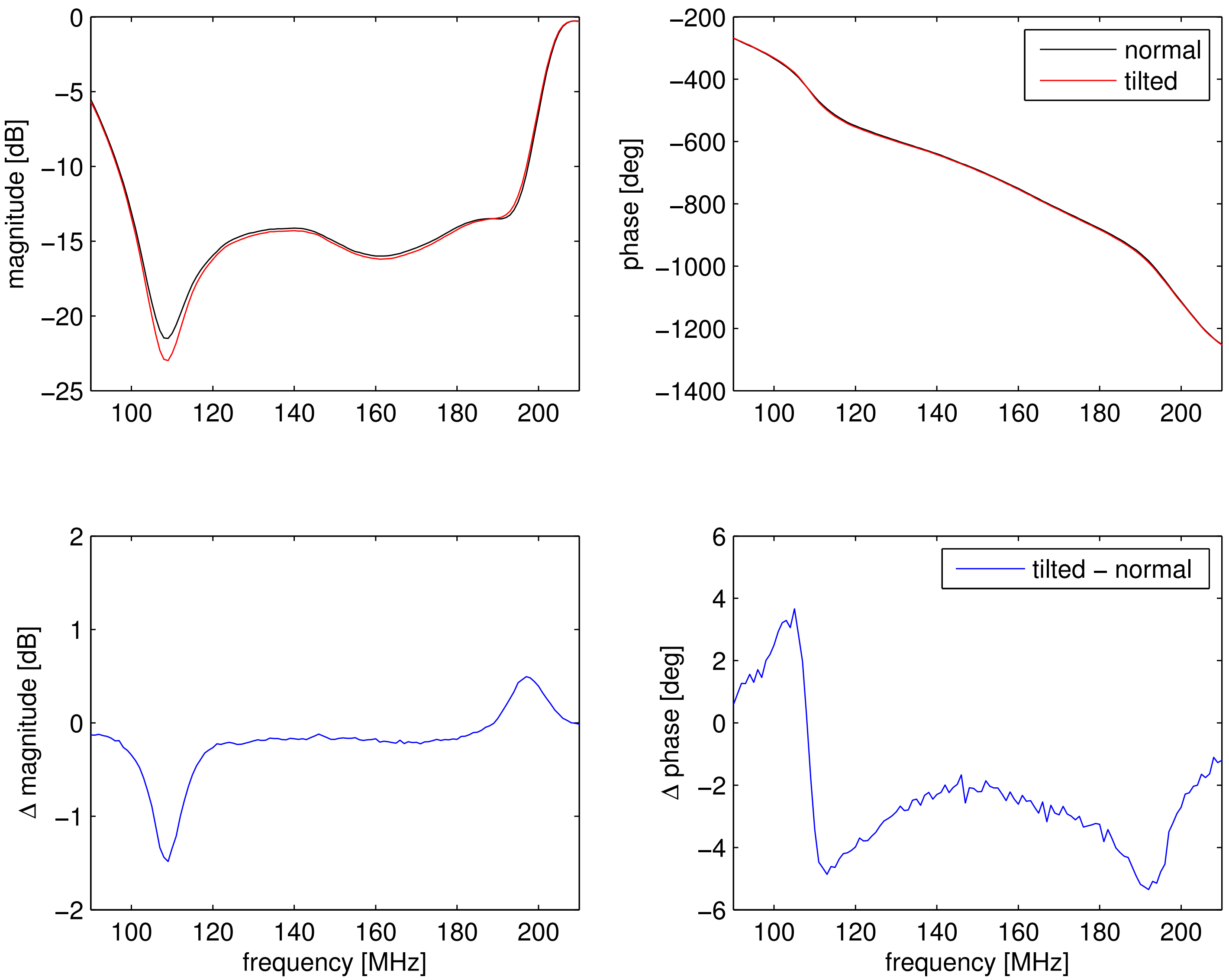

Figure 2: Tilting (lifting north corner by 1 inch).

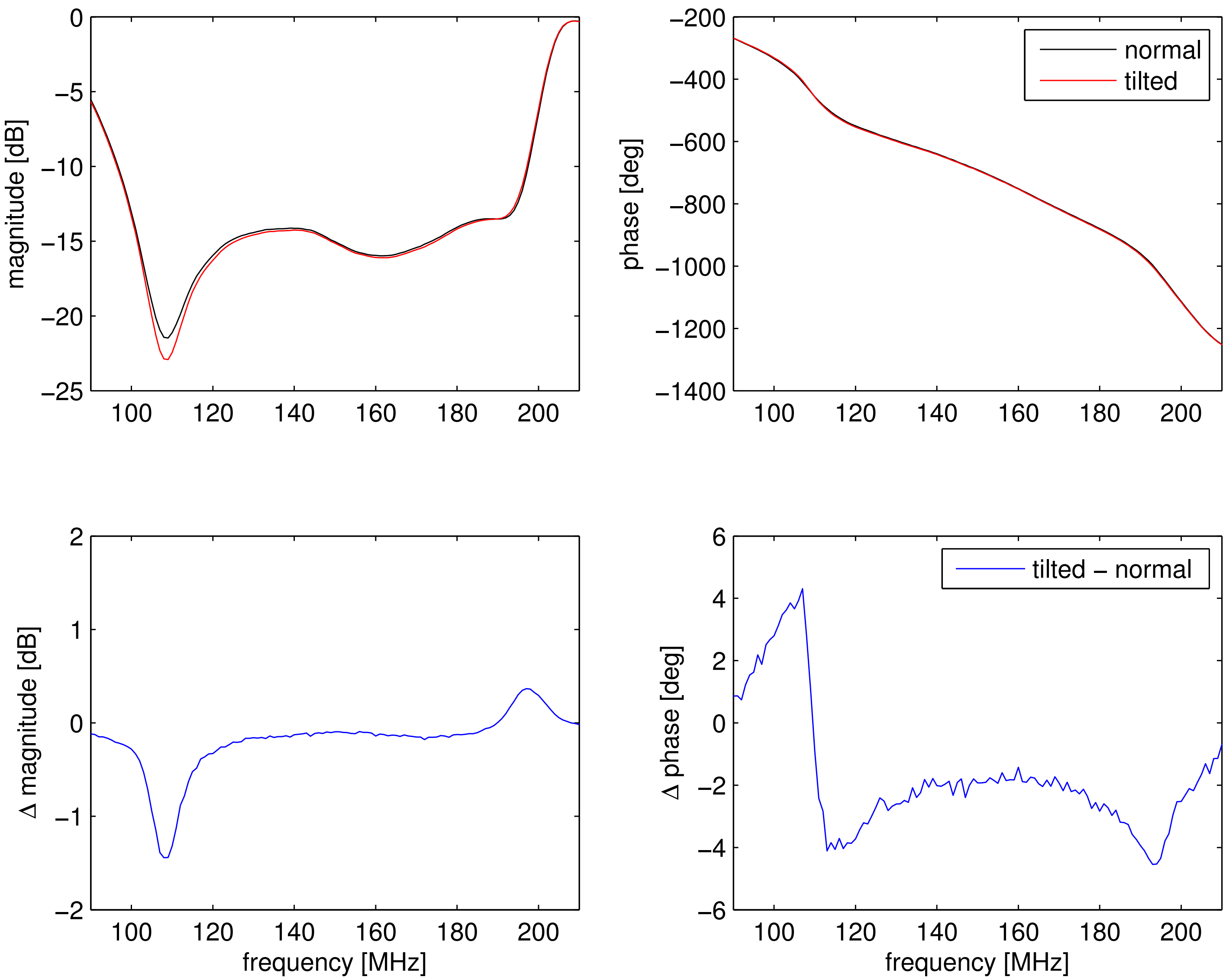

Figure 3: Tilting (lifting south corner by 1 inch).

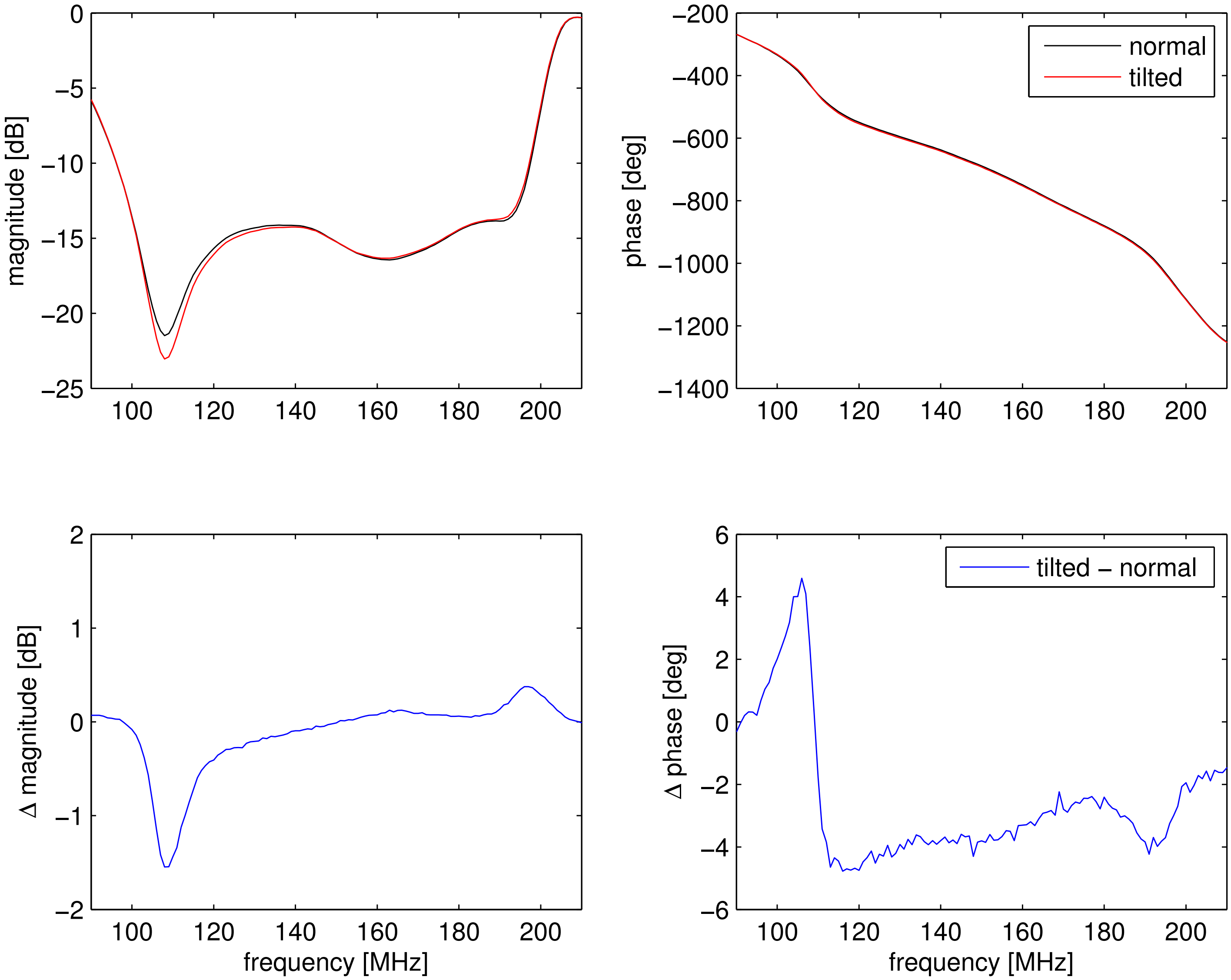

Figure 4: Tilting (lifting east corner by 1 inch).

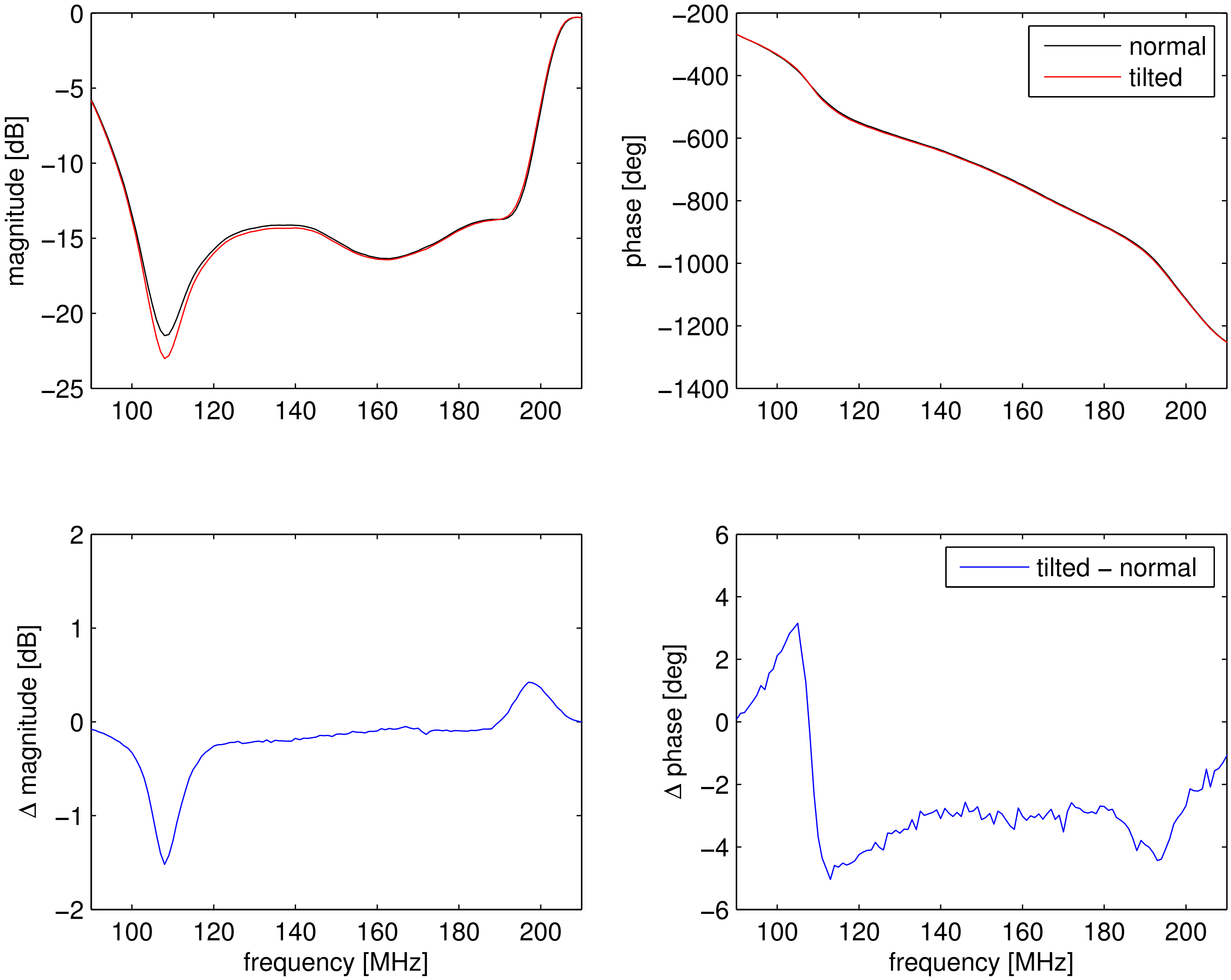

Figure 5: Tilting (lifting west corner by 1 inch).

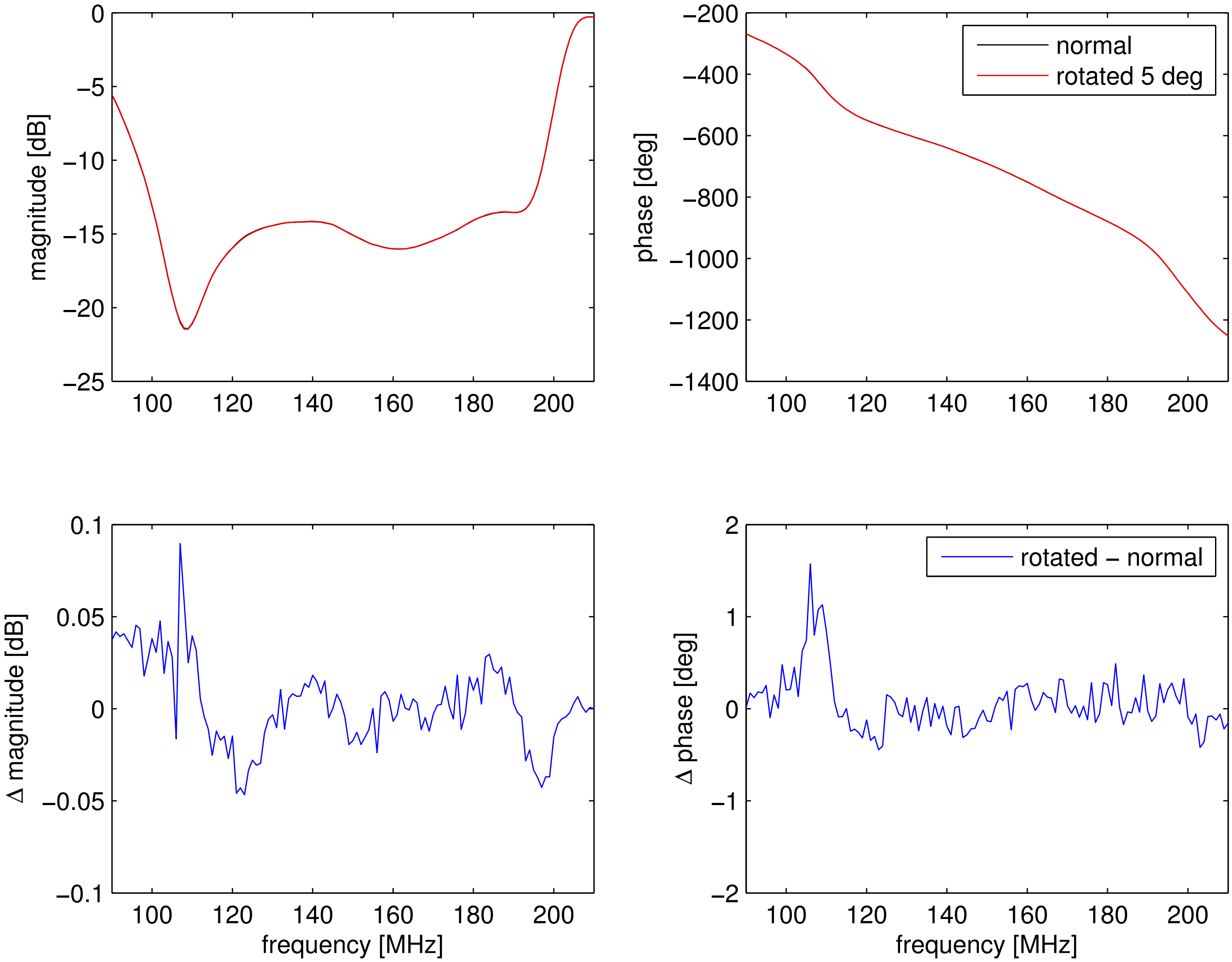

Figure 6: Rotating 5 degrees eastward.

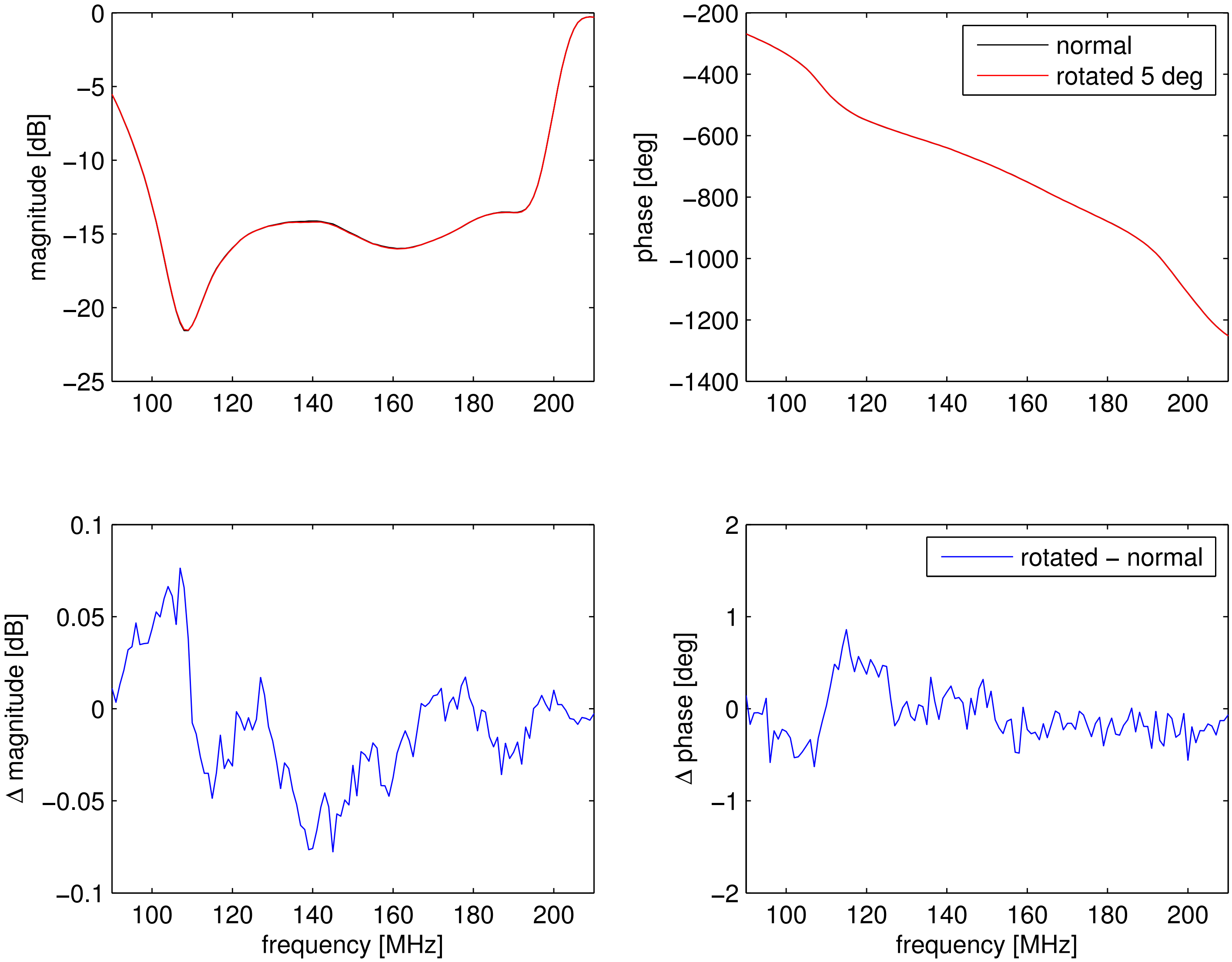

Figure 7: Rotating 5 degrees westward.

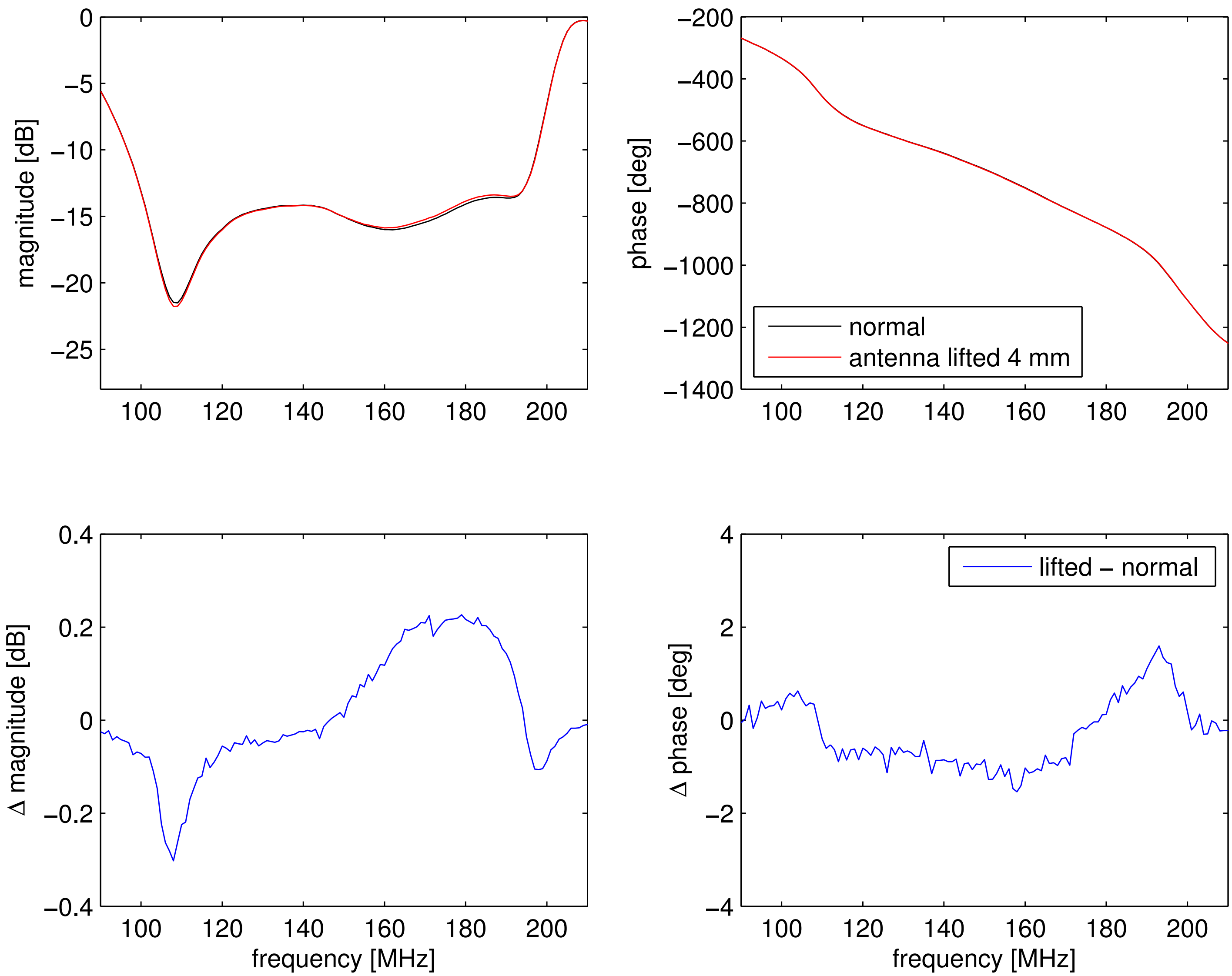

Figure 8: Lifting 4 mm from ground plane.

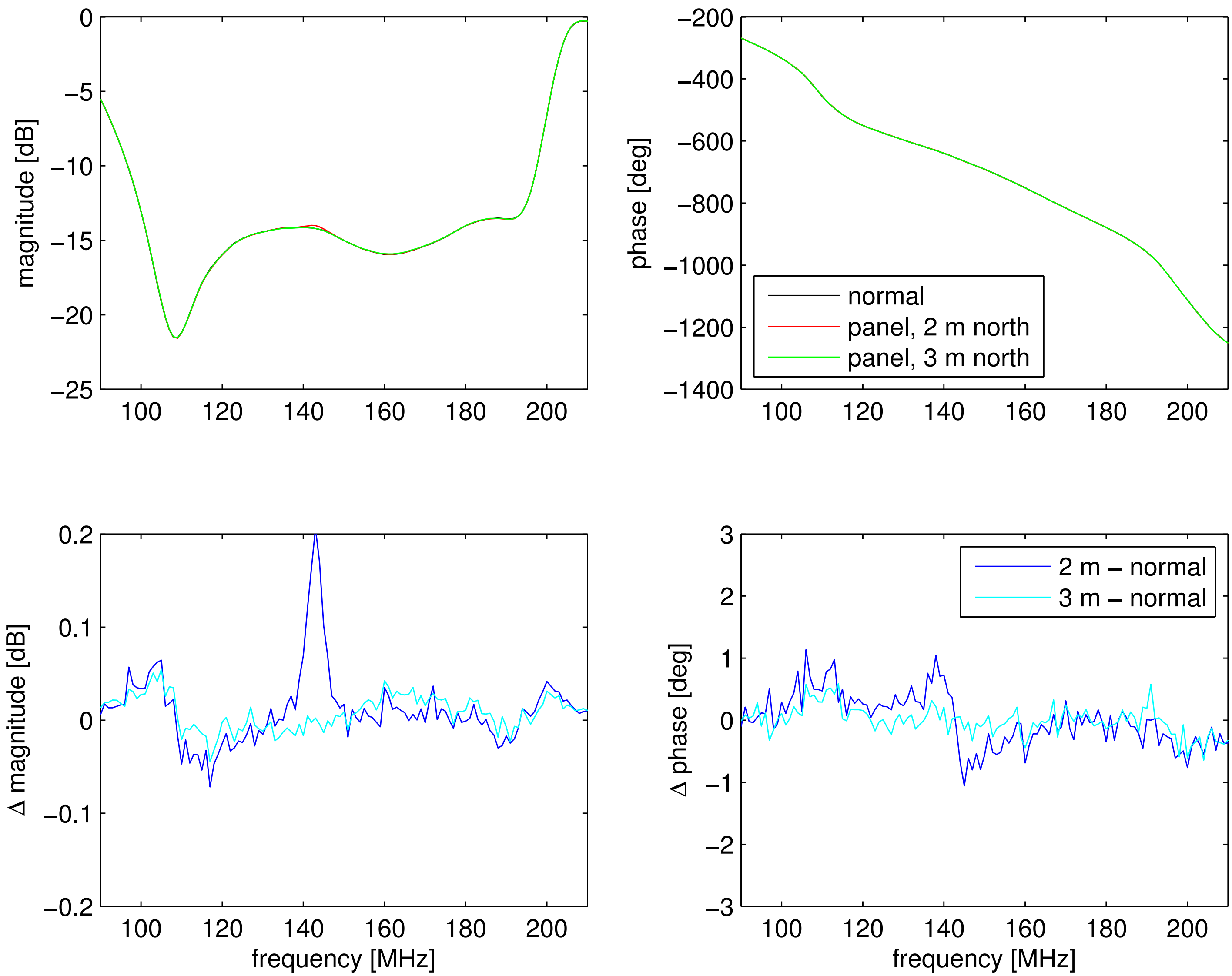

Figure 9: Metal panel, north of antenna.

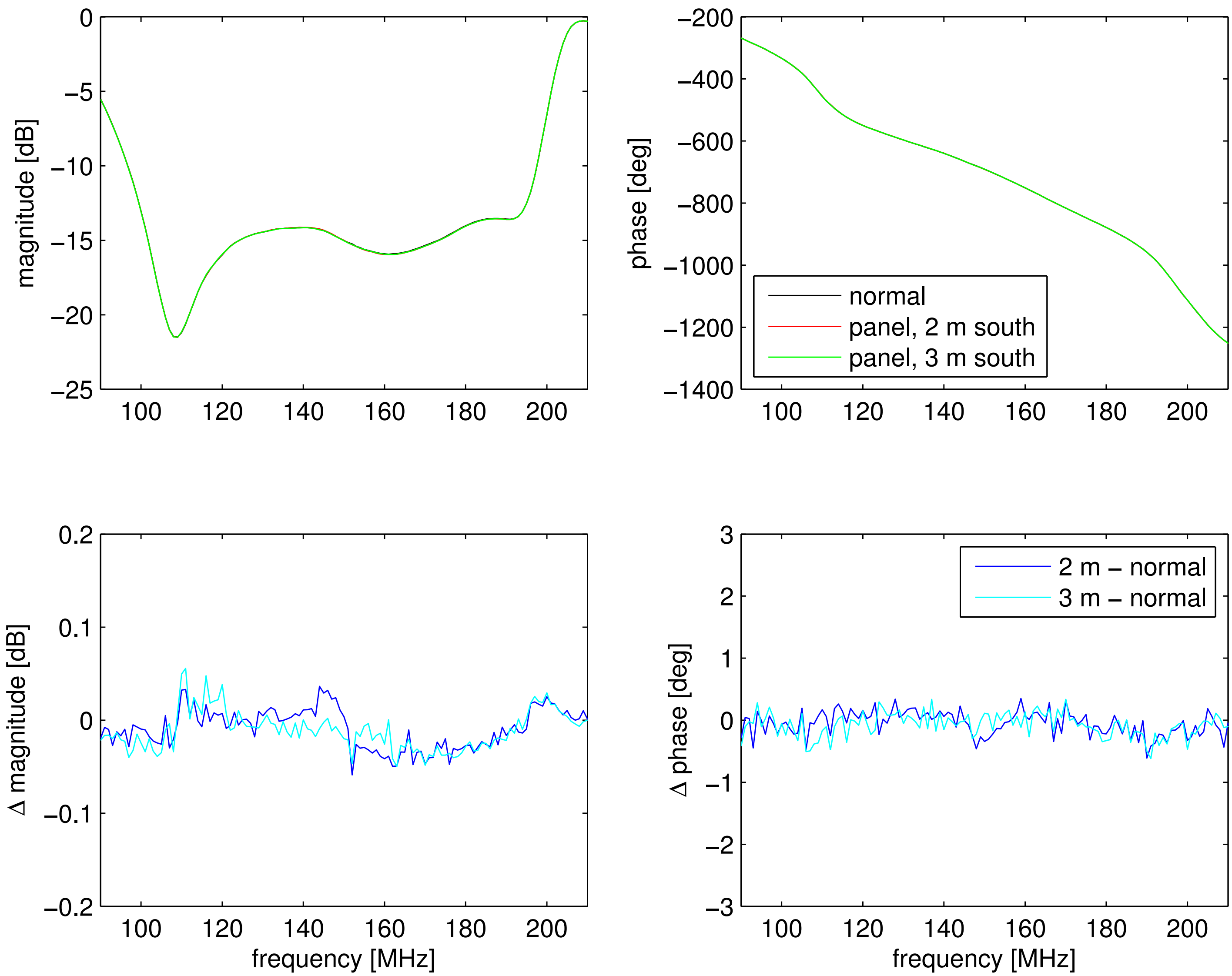

Figure 10: Metal panel, south of antenna.

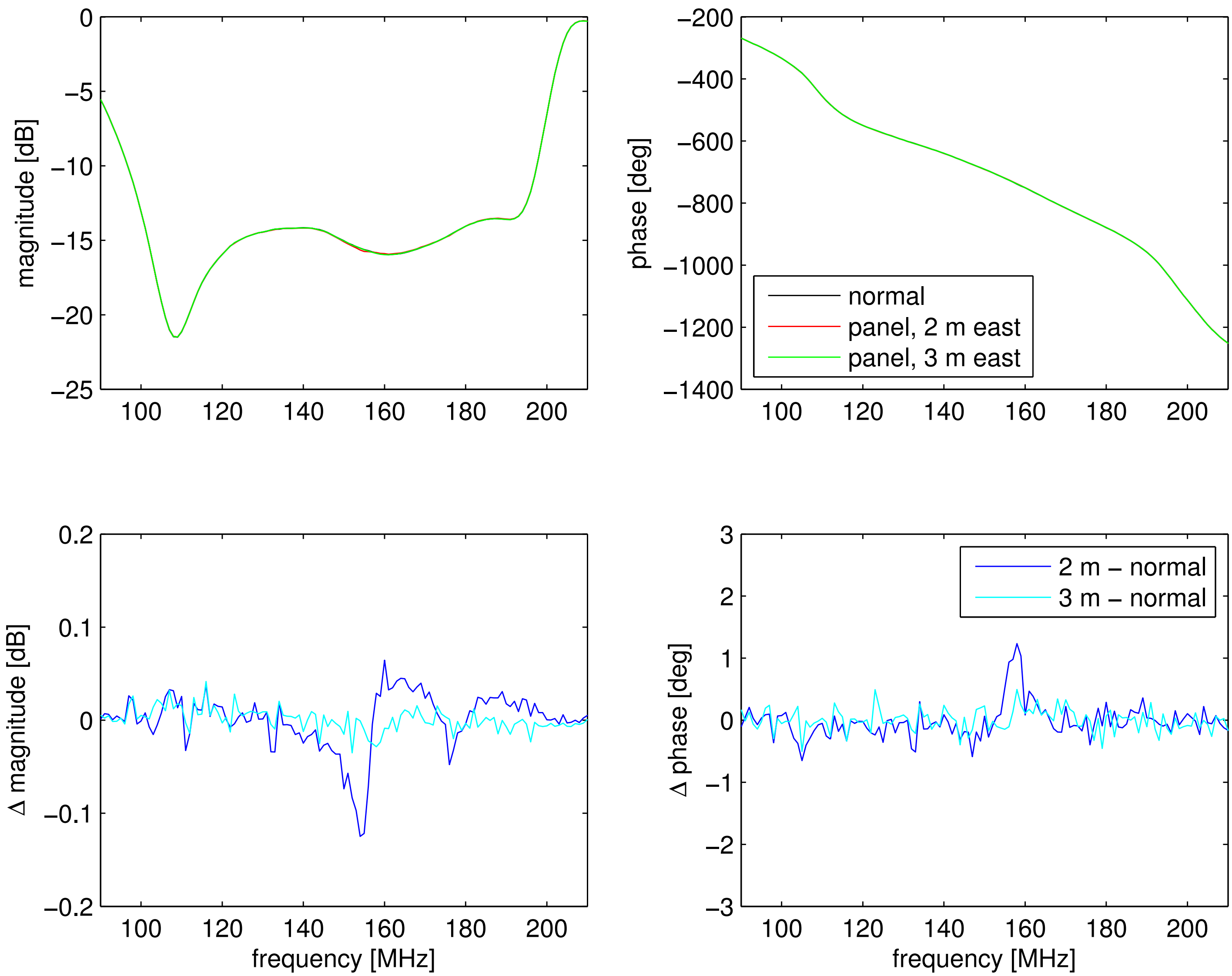

Figure 11: Metal panel, east of antenna.

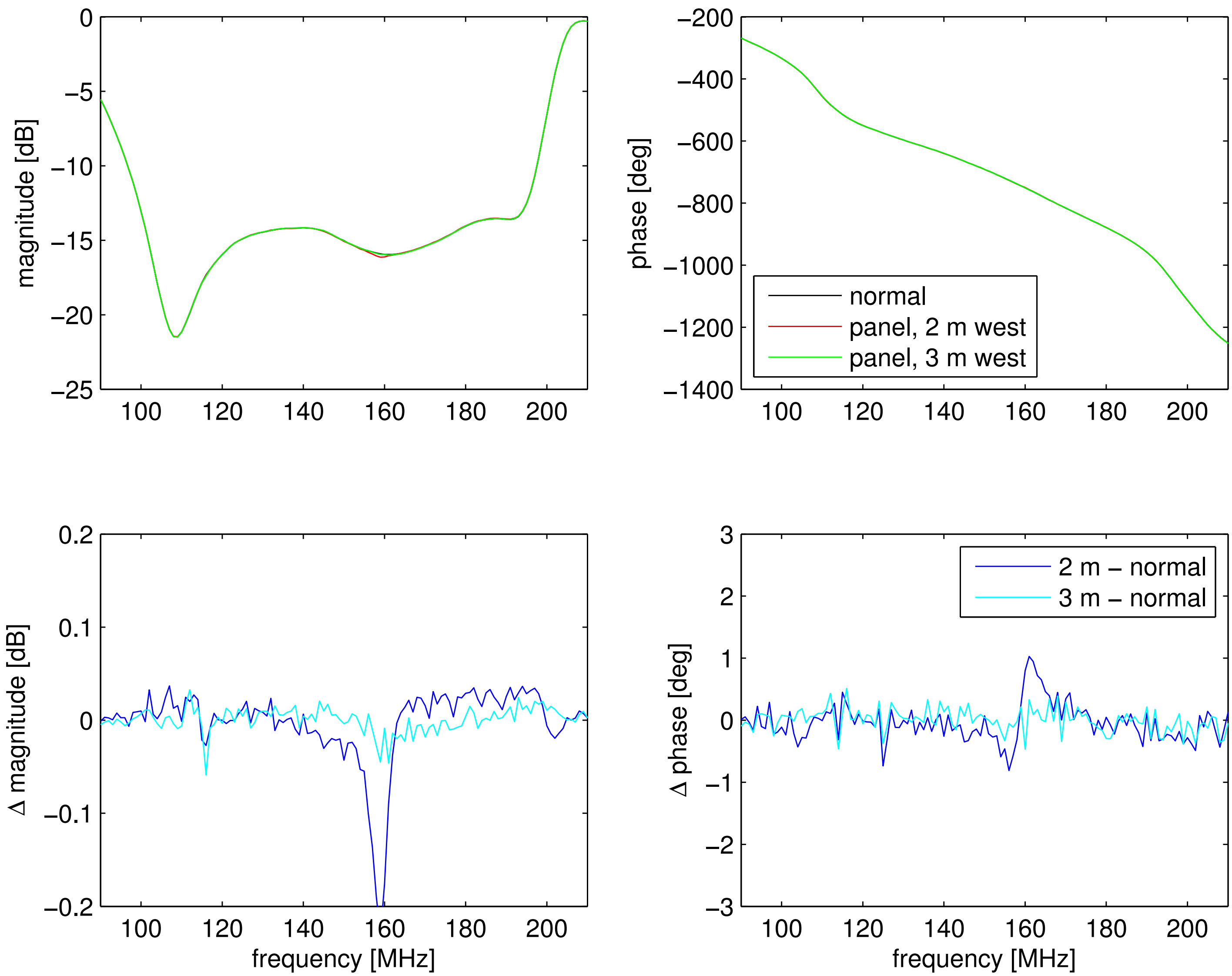

Figure 12: Metal panel, west of antenna.

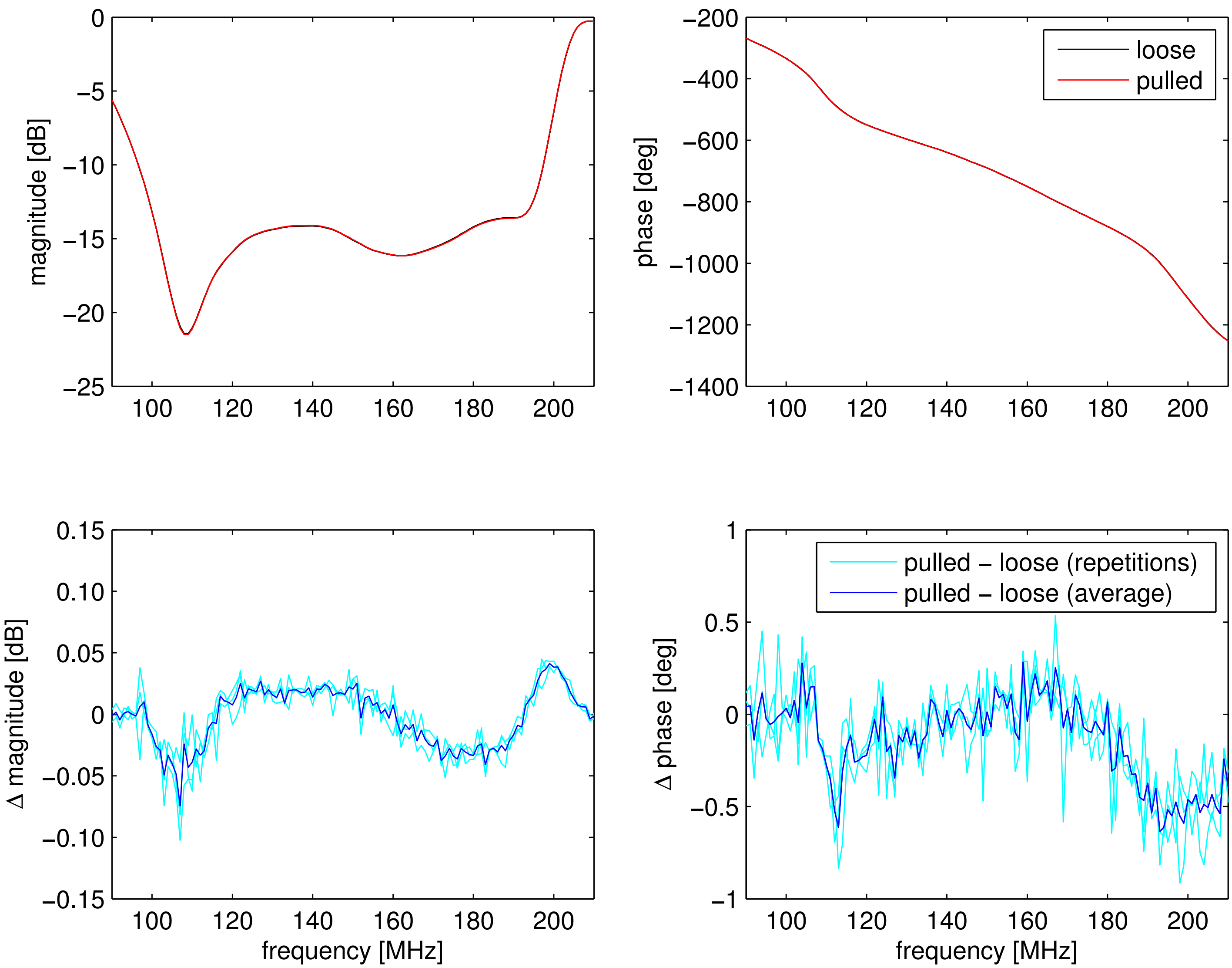

Figure 13: Pulling, north-south direction.

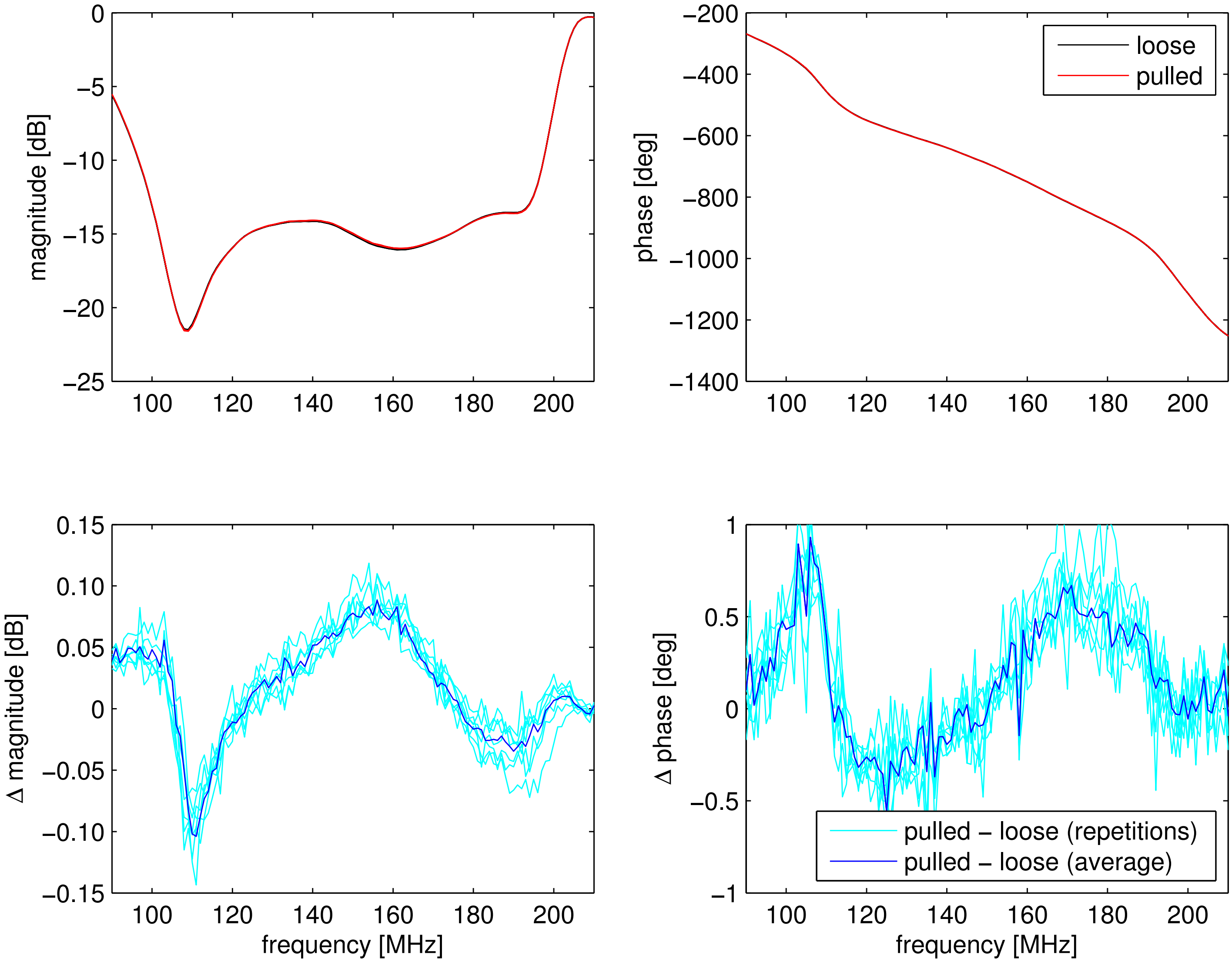

Figure 14: Pulling, east-west direction.

Table 1: Effect of perturbations on antenna reflection coefficient ($\Delta = \Gamma_{changed} - \Gamma_{ref}$).

Perturbation	$\Delta\|\Gamma\|$ [dB]	$\Delta\Phi(\Gamma)$ [°]	Comments
Raising balun by 1.5 mm off base	$\pm 0.1^a$	$\pm 1.5^b$	^{a} Peak at 180 MHz. ^{b} Peak at 192 MHz.
Tilting antenna by 1.7° in any direction	$\pm 1.5^a$	$\pm 5^b$	^{a} Peaks at 108 and 197 MHz. ^{b} Peaks in [105, 120] MHz, and at 192 MHz.
Rotating antenna by 5° about its central vertical axis	$\pm 0.07^a$	$\pm 1^b$	^{a} Even structure between 80 and 200 MHz. ^{b} Peaks below 130 MHz.
Lifting antenna by 4 mm above ground	$\pm 0.3^a$	$\pm 2^b$	^{a} Peaks at 108 and 180 MHz. ^{b} Peak at 192 MHz.
Ground plane change 2 m away	$\pm 0.2^a$	$\pm 1^b$	^{a} Peaks between 140 and 160 MHz. ^{b} Peaks below 180 MHz.
Ground plane change 3 m away	± 0.05	± 0.5	Significant only for changes north and south of antenna.
Antenna pulling N-S	$\pm 0.05^a$	$\pm 0.5^b$	^{a} Peaks at 108 and 198 MHz. ^{b} Peaks at 113 and 200 MHz.
Antenna pulling E-W	$\pm 0.1^a$	$\pm 1^b$	^{a} Peak at 110 MHz. ^{b} Peak at 105 MHz.

2 Summary

This section and table 1 summarize the results.

1. *Deforming the antenna*: Raising the balun by 1.5 mm off the base produces residuals of 0.1 dB in magnitude and 1.5° in phase, above 150 MHz.

2. *Tilting the antenna*: Tilting the antenna in any direction produces a similar residual profile. In magnitude, a large peak of -1.5 dB occurs at 108 MHz, and a second peak of 0.5 dB appears at 197 MHz. In phase, the characteristic signature occurs broadly between 80 and 220 MHz with changes within [-5°, 4°]. It involves a sudden change at $\sim$105 MHz and a slower return to normal at $\sim$192 MHz.

3. *Rotating the antenna*: Rotating the antenna by 5° eastward or westward produces residuals with similar structure, with amplitude of order 0.07 dB in magnitude and 1° in phase between 80 and 200 MHz.

4. *Lifting the antenna*: Lifting the antenna by 4 mm above the ground plane produces residuals of 0.3 dB in magnitude and 2° in phase. The largest magnitude peak occurs at 108 MHz and the shape resembles that of the tilting tests.

5. *Modifying ground plane*: Adding a metal panel 2 m away from the center of the antenna (blue lines) at a height of 1 inch produces changes of up to $\pm$0.2 dB in magnitude and $\pm$1° in phase. The most notorious features occur between 130 and 160 MHz. When the panel is placed 3 m away (cyan lines) the residuals are reduced substantially. The largest remaining residuals are those of the north and south cases, of $\sim$0.03 dB in magnitude.

6. *Pulling the antenna*: The antenna was pulled 10 times in the N-S and E-W directions, approximately 4 mm from its natural state. Measurements were performed $before$ (reference) and $while$ pulling. The plots show in cyan the measurements for which the reference traces are similar. Those with significantly different reference traces were discarded since their comparison is not directly informative. Starting from the same condition (similar reference), the reflection coefficient when pulling the antenna is very consistent. For that reason the average trace was computed and showed in blue in the plots. For changes in the N-S direction, the residuals are of $\pm$0.05 dB in magnitude and 0.5° in phase. Changes in the E-W direction cause larger differences, of $\pm$0.1 dB in magnitude and 1° in phase.