Some comments on QST Nov 2016 article "Controlling Unwanted Feed Line Resonance in VHF Vertical Antennas" by K4ERO.

Background

This article provides some NEC calculations and observations of a GP antenna with 4 radials and a simulation of possible "feedline" currents (i.e., coaxial cable outer braid common-mode currents) with some feedline variation of distance to a large ground connected to the bottom of the feedline, or not. Some implications of the effects of feedline chokes are provided.

It is well know that NEC is an imperfect, though often valuable, tool for antenna analysis with several limitations including close wires and realistic ground effects. Calculation of coaxial cable common-mode currents is sometimes attempted by adding a single wire that is intended to simulate the coax outer braid current. The reliability of this technique appears not to be firmly established.

Sketched E fields

The first thing in the article that caught my eye is Figure 4 which shows a sketch of electric field lines for a 4 radial GP, each ~ λ/4, a λ/4 vertical and with a single "feedwire" underneath an about λ/2 path to simulate coaxial outer braid common-mode current. There is a gap at the top of the wire path corresponding as a simulation of a choke such as might be done with a balun or ferrite cores. The sketch, reproduced below, is obviously not from a calculation since the E fields are often not perpendicular to conductors. Furthermore, the caption (and text) suggests the dominant effect here is due to displacement current across the gap rather than near field to conductor coupling.
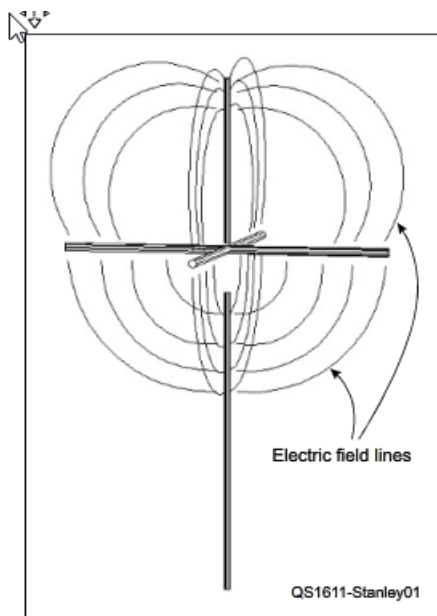

Electric field lines

QS1611-Stanley01

Figure 4 — Electric fields couple across a gap by the electromagnetic mutual coupling effect.

EM Calculations

With this as incentive, and suspecting that the sketch may be a limited representation of reality, I have made a set of runs using a full up, and pricey, Maxwell equation solver (but with fat 1m thick square wires due to resolution limitations) called MAGIC. These include simulations with $\lambda/4$ and $\lambda/2$ feedlines, with or without a large conducting ground beneath, with or without a gap at the top of the feedline and with or without a gap between the bottom of the feed line and the ground (only for the cases with a ground). That is 12 basic cases in addition to some secondary cases with no feed line at all and another with a variation of feedline length.

First here is a simulation of the "feedline" wire of about half a wavelength with a gap at the top corresponding to the Figure 4 sketch. This was done at 3.5 MHz, but the frequency mostly does not matter. Case P from the table at the end provided a 3D image of the wires (current source is at the base of the antenna) and an E field denoted by vectors (in a vertical plane through 2 of the radials) in the associated snapshot in time. [For all cases reported here, there are no more transient effects and the fields and currents have reached a sinusoidal "steady state."] The absolute scale is not important but in this example, and all others, the vector lengths use a log scaling to avoid having large E vectors dominate the image. Thus the smaller vectors are in reality even relatively smaller than they appear, but the directions are true. The gap in the "feedline" corresponds to about 350 ohms capacitive reactance, a bit less than planned but still much greater than the antenna impedance. In a later test the gap was doubled in size giving about 525 ohms capacitive while the feedline currents were reduced by ~20% for this one example. It should be noted that the feedline gap used here is not really of the same complex impedance as would be obtained by coiled coax or ferrite beads since the gap is purely capacitive although that may not matter.
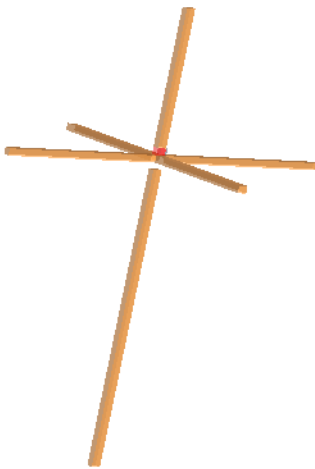

Fig 1. 3D model case P similar to sketch.

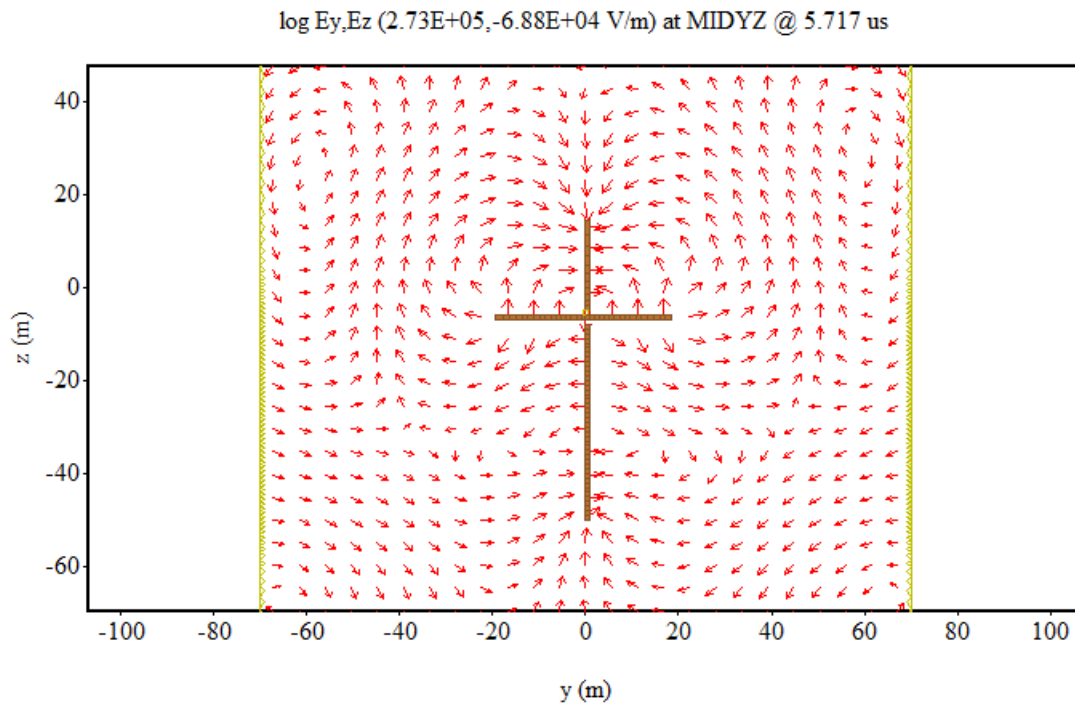log Ey,Ez (2.73E+05,-6.88E+04 V/m) at MIDYZ @ 5.717 us

Fig 2. Case P E vector snapshot.

This wide view vector plot has an attempted balance between resolution, vector density and lengths but leaves some artificial overlap of vectors at the right sides of the antenna and feedline due to long vectors on the left crossing the conductors. More local plots will be shown next. Still this plot makes it pretty clear that there a significant difference of the E field direction under the radials as compared with the sketch, suggesting the sketch may not be too meaningful. To clarify the vector plots, two more local plots were generated, first from a quadrant above the GP and then from a quadrant below.
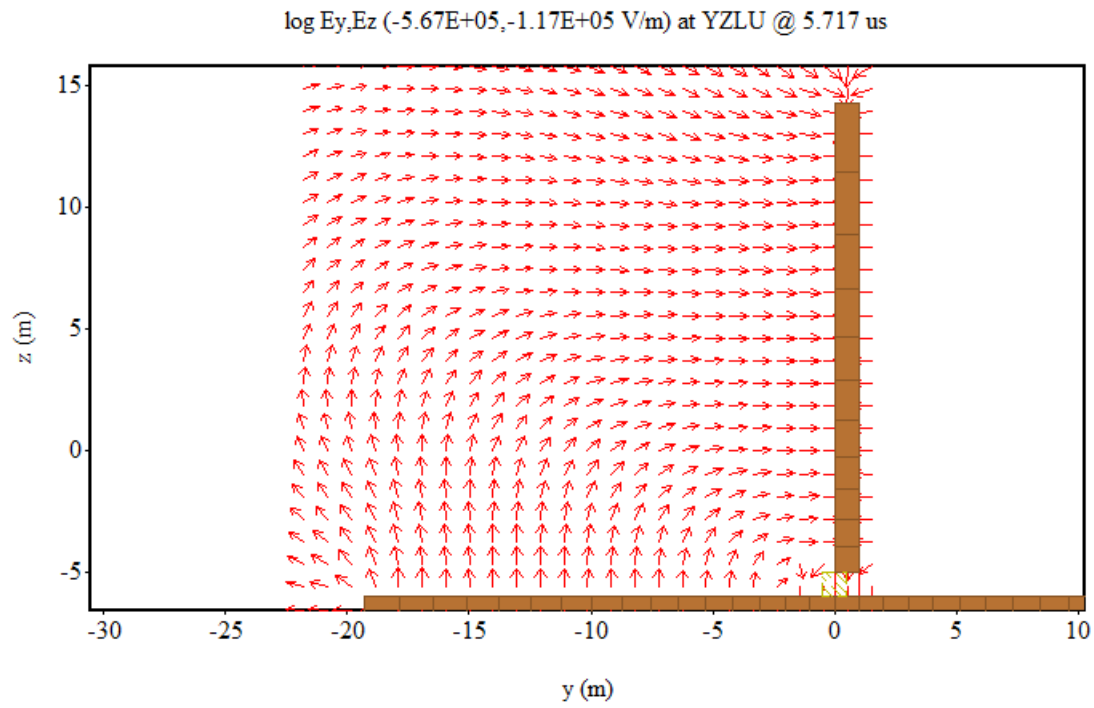
Fig 3. Detailed case P E vector plot, an upper quadrant.

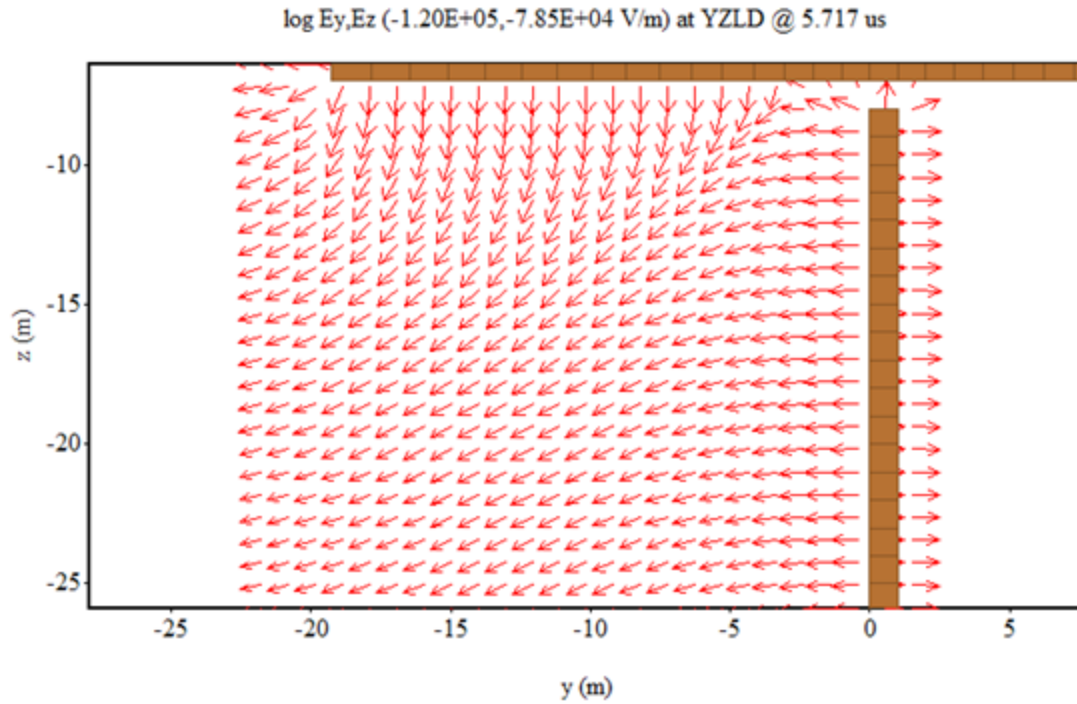log Ey,Ez (-1.20E+05,-7.85E+04 V/m) at YZLD @ 5.717 us

Fig 4. Detailed case P E vector plot, a lower quadrant.

The E field pattern in the above plot is clearly different from the sketch.

The magnitude of the E field averaged over a period, for the sketch case P, is shown in the next plot below with a gap at top. Note that the field at the feedline becomes small a bit more than half way down and this corresponds to where the E field direction near the feedline reverses in the vector plot in Figure 2. At the times of all the plots, the fields have come to steady state and just oscillate with time.
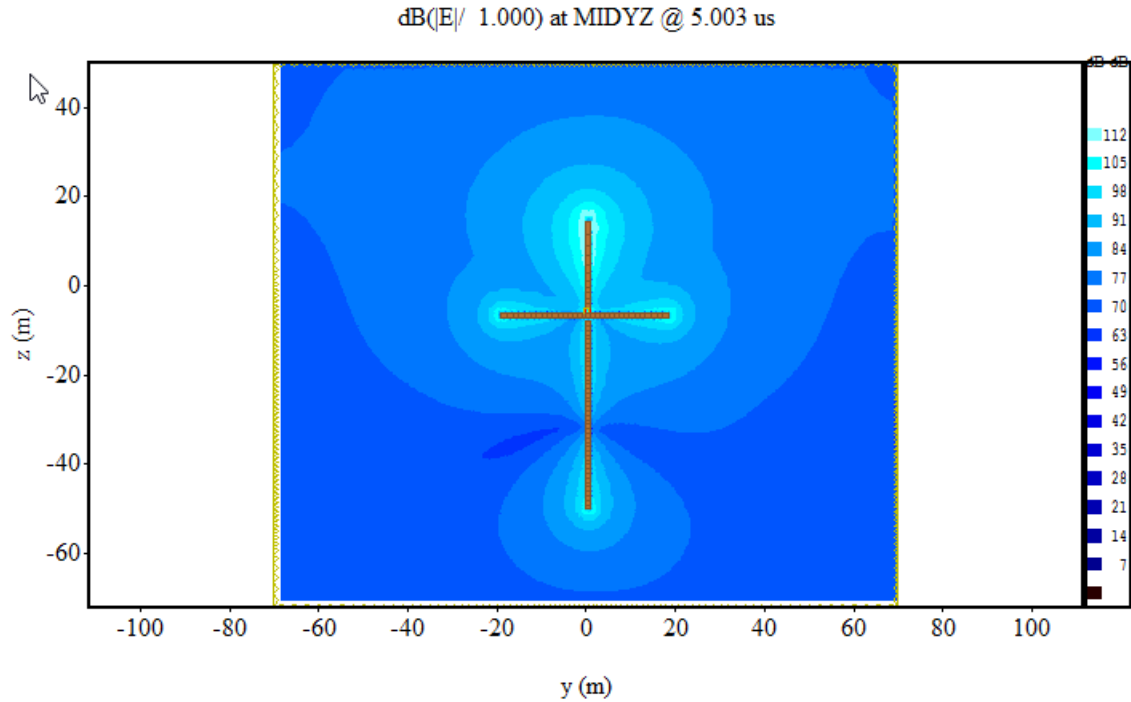
dB(|E|/ 1.000) at MIDYZ @ 5.003 us

Fig 5. Case P, with feedline gap, E average magnitude plot.

For comparison, next is the case with no gap E field (G) showing only modest differences. In both of these cases, the current near the top of the feedline is ~ 5% of the vertical antenna current and the antenna and radial currents are quite similar to the case with no feedline at all (see later plot). [Note that all references in this entire note to measured current in the simulation are from an integration of the H field (or B since B=H in free space) along a closed loop. The current through the loop so measured is really the sum of conduction current and displacement current. If the loop is around a wire away from ends, the result is almost all conduction current. This is true for the antenna, the base of the radials and the top of the feed line or bottom of the feed line for the big ground case IF there is no gap. If there is a gap and the current sensing loop is near it, the measured current can be largely displacement current since the conduction current must go to zero at the end of the wire. Of course, change does accumulate at the end of the wires giving rise to potentially large electric fields, and displacement currents, there. These fields also provide an indication of the current in the wire away from the end.]

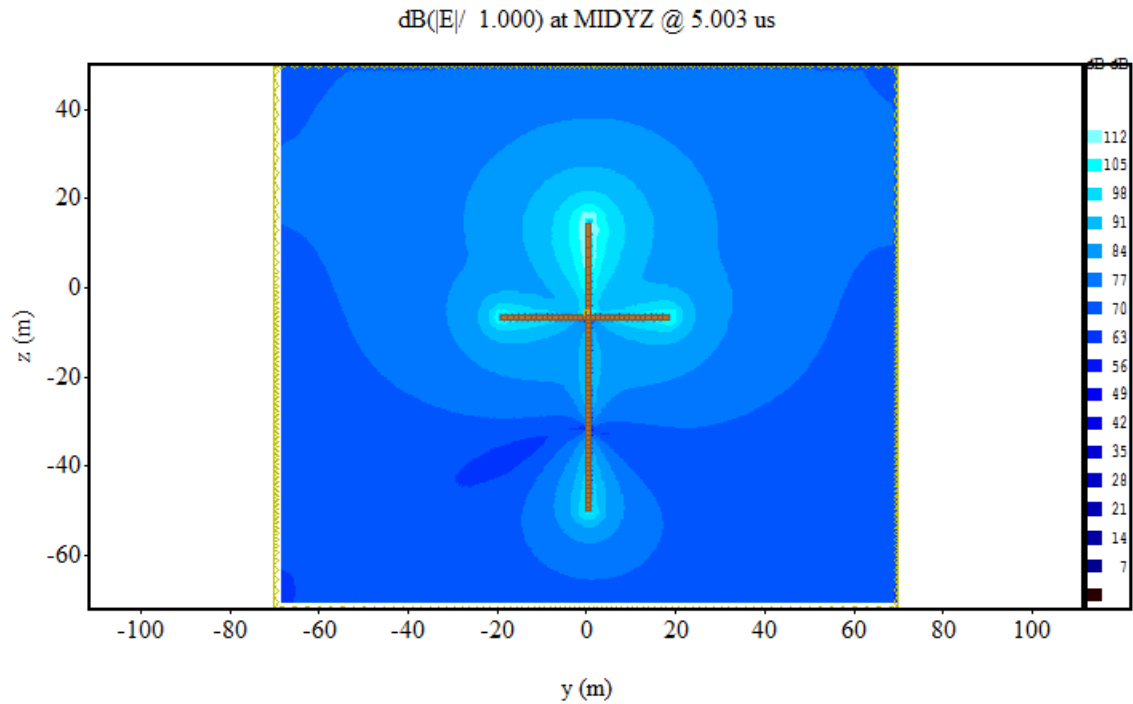dB(|E|/ 1.000) at MIDYZ @ 5.003 us

Fig 6. Case G, like P but with no feedline gap, E magnitude plot.

This is consistent with the information from the article indicating a non-grounded $\lambda/2$ feedline provides little effect from common-mode currents with or without a gap.

Ground Effects

Next we compare the examples in the article Fig 1 but as calculated by MAGIC. Both are over, and connected to, a large conducting ground layer at the bottom of the feed line.   First we look at the fields for the $\lambda/2$ case (C) with a large ground connected beneath and no gaps. This appears to be much different from the cases with no ground discussed before, and the current at the top of the feedline is comparable with that in the antenna although they are not in phase (see the table at the end). This would appear to be the resonant (and very bad) effect case as discussed in the article.
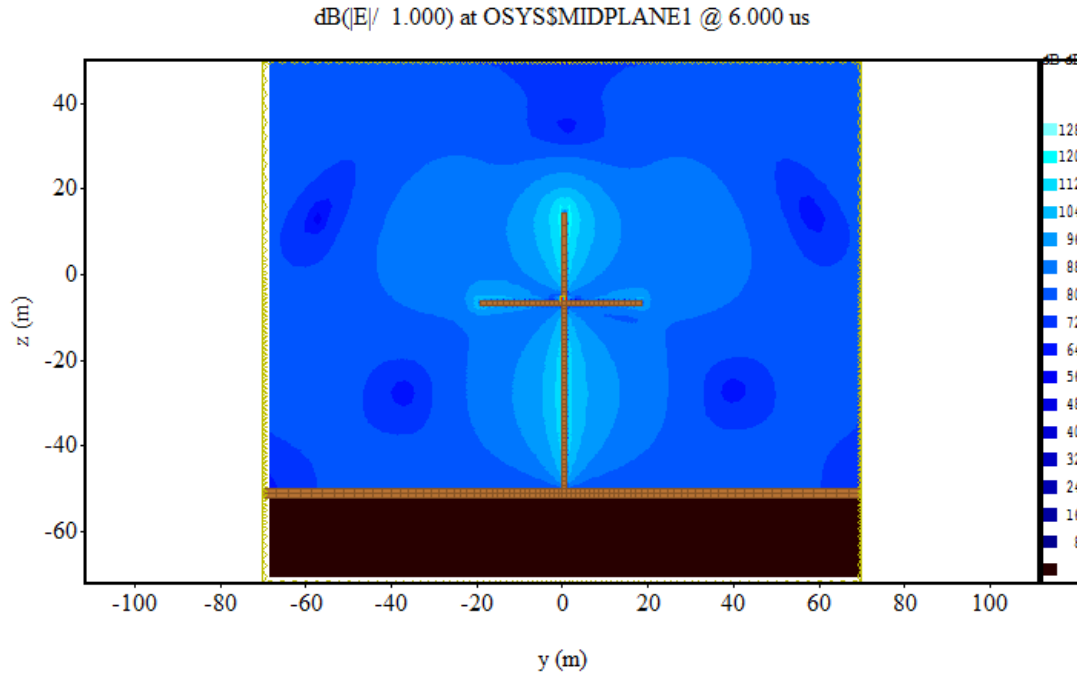
dB(|E|/ 1.000) at OSYS$MIDPLANE1 @ 6.000 us

Fig 7. Case C, like P but with big ground and no gap, E magnitude plot.

An additional 3 runs at λ/2 were made with the ground but with gaps (1 or 2) imposed at the top or bottom or both. In all these 3 cases, there was little or no similar resonant effect from strong common-mode currents. So any gap appears to cut the common-mode current substantially. An example is in Fig 8.

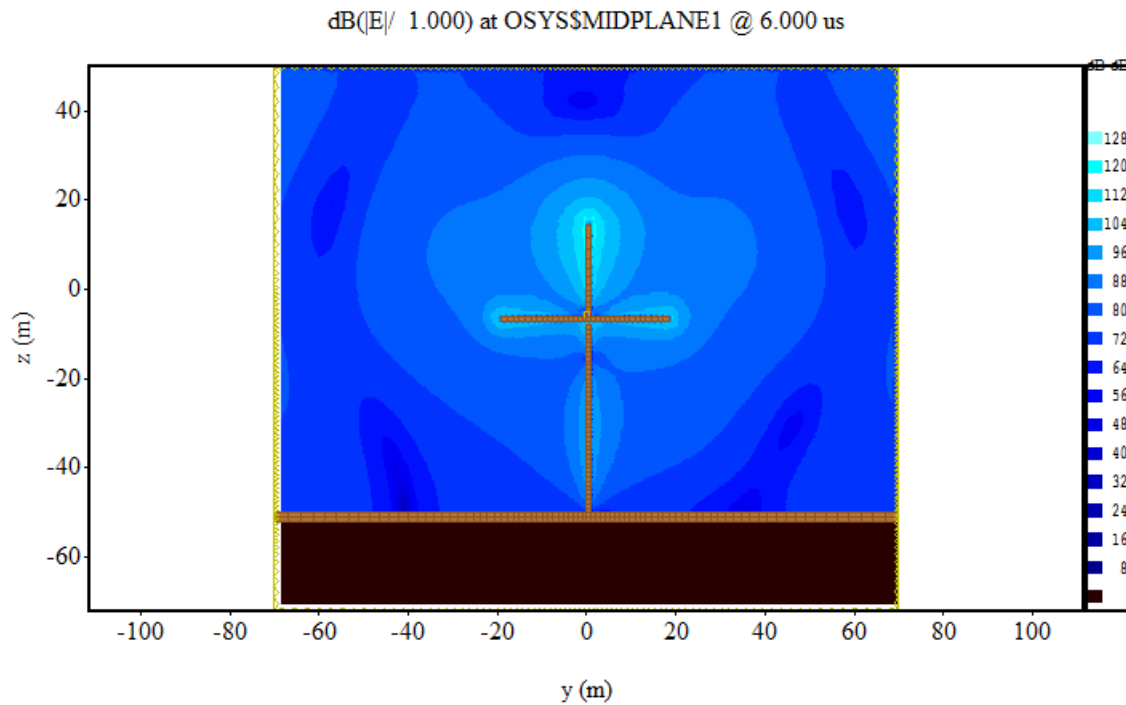dB(|E|/ 1.000) at OSYS$MIDPLANE1 @ 6.000 us

Fig 8. Case B, like C but with a gap at the top of the feedline, E magnitude plot.

For the $\lambda/4$ case (D) with a ground and no gaps, the E field plot below shows only small fields near the feedline suggesting minimal effect. This is consistent with the currents measured including an imposed antenna current of 10 and a top of feedline current of about 1.
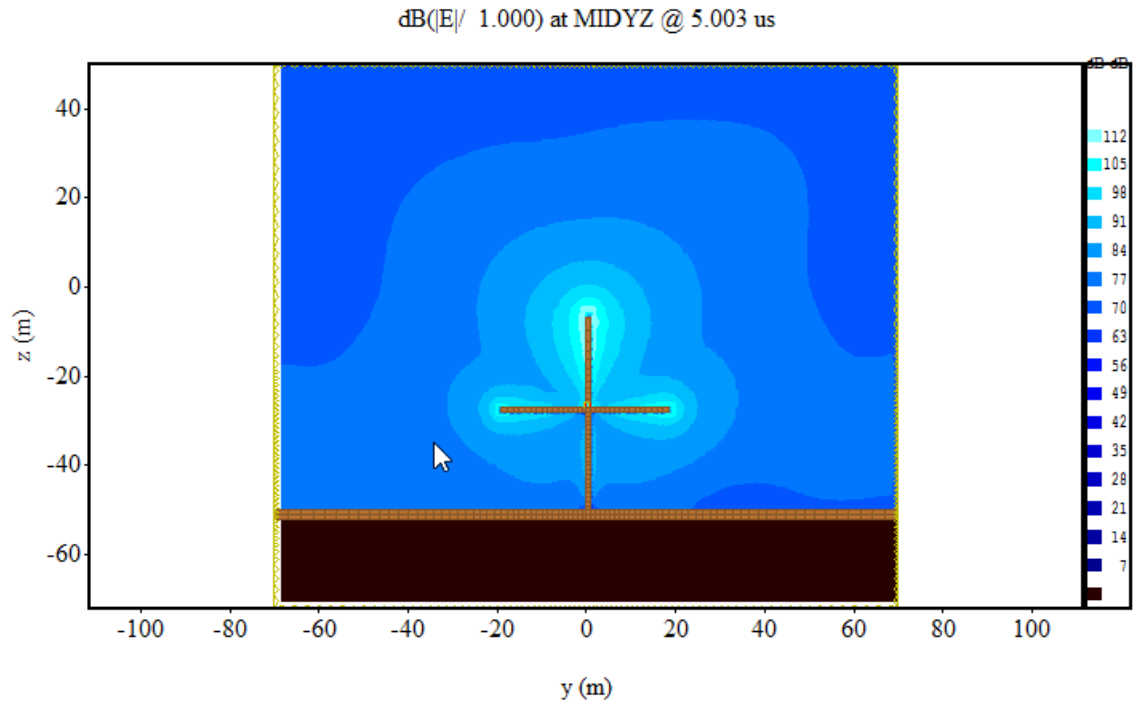

Fig 9. Case D, $\lambda/4$ feedline, big ground and no gaps, E magnitude plot.

Other $\lambda/4$ cases were run. Both (E) with a gap at the top of the feedline and (N) with both feedline gaps indicted little change from the no gap case. First E, which has feedline currents of 1 at the top and 3.8 at bottom but nearly standard radial currents.
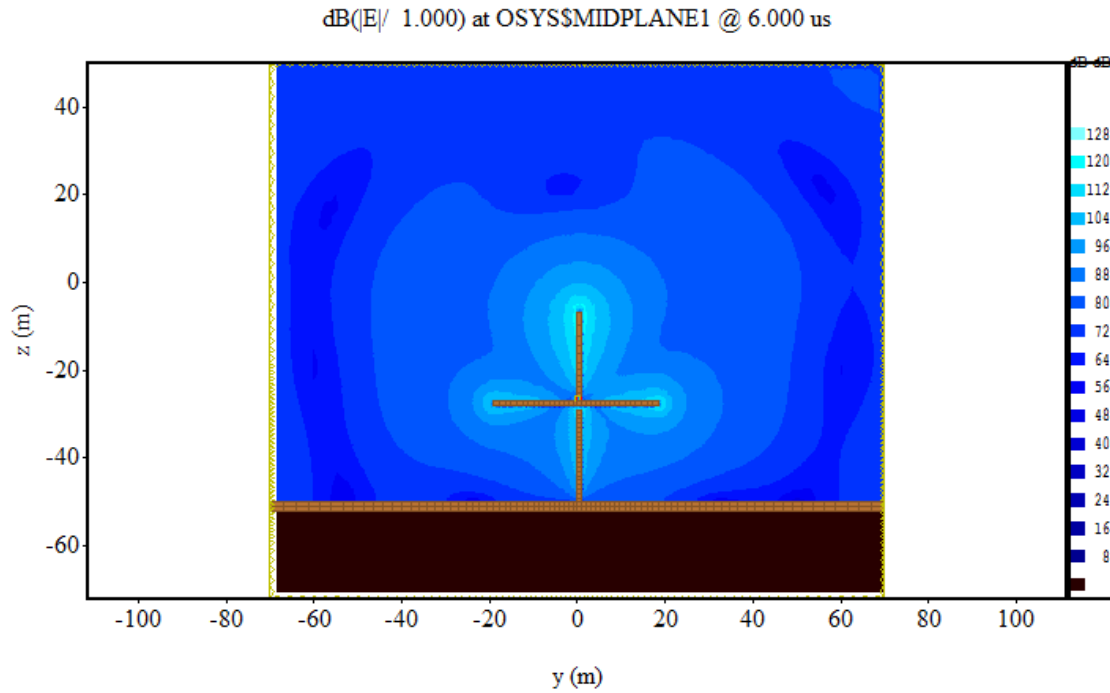
Fig 9. Case E, $\lambda/4$ feedline, big ground and top gap, E magnitude plot.

Then N, with currents of 1 top and 1 bottom, shows little effect of common-mode currents.
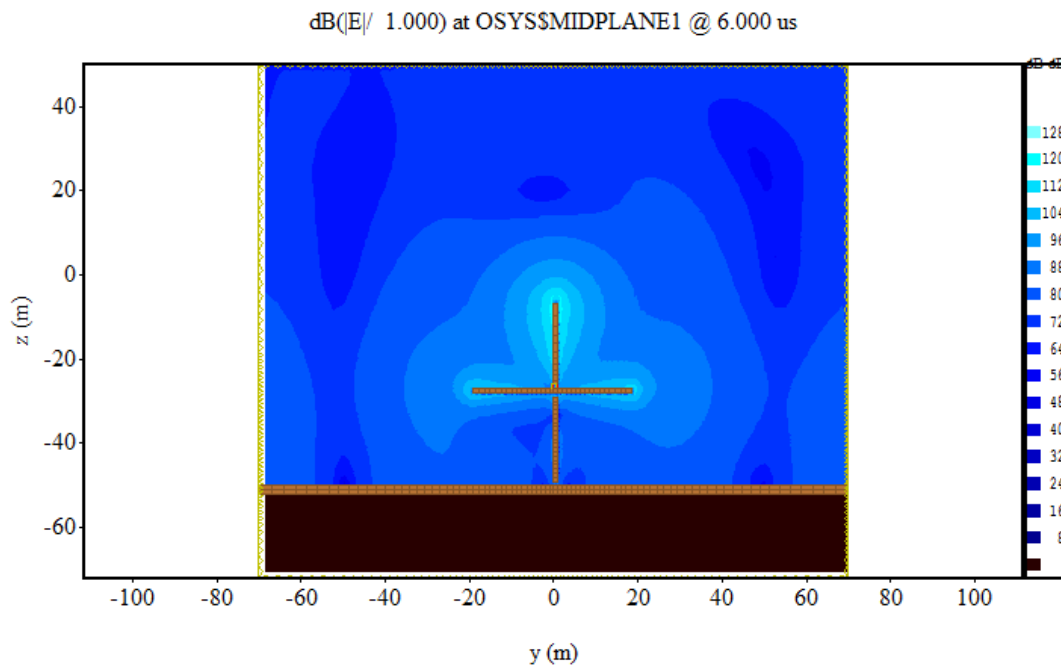

Fig 10. Case N, $\lambda/4$ feedline, big ground and top and bottom gaps, E magnitude plot.

Finally the case (L) with a gap only at the bottom at the ground was run. The E field plot below suggests a difference from the above case but now the currents are antenna 10 and top of feedline 4.2 with the phases of the different currents different from expected so it is significantly disturbed. With a big E field at the gap.
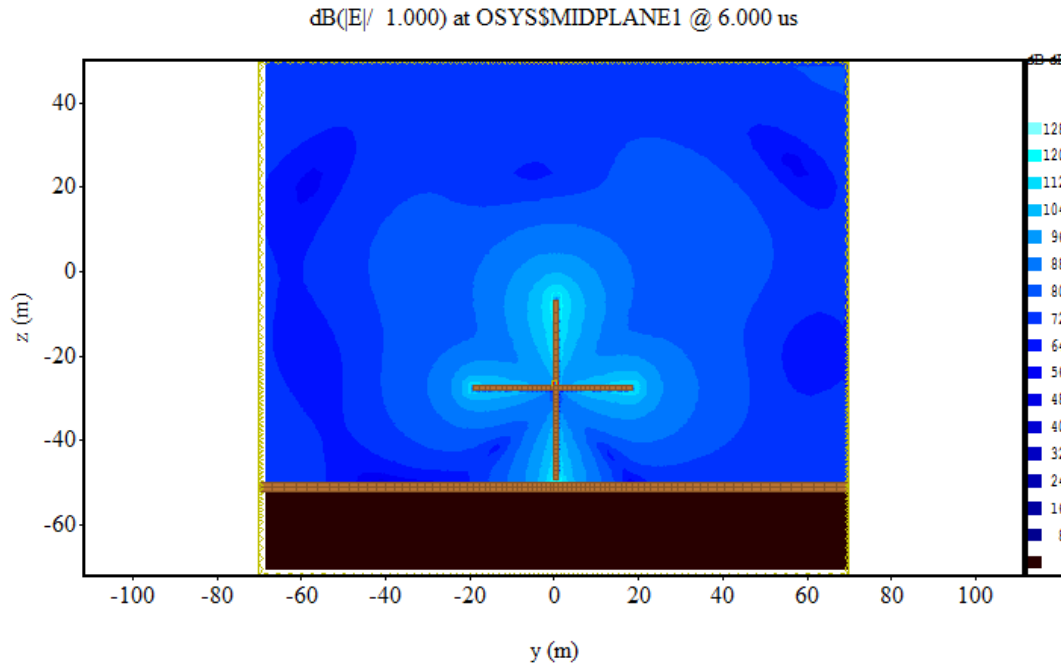

Fig 11. Case L, $\lambda/4$ feedline, big ground and only bottom gap, E magnitude plot.

Non-Ground Effects

Finally we look at the $\lambda/4$ case with no ground below. Case (H) with no gap gives a strong field below the antenna and the current at the top of the feedline is 7.7 indicating strong disturbance. Note that this is the same as adding a fifth radial that is opposite the antenna direction.
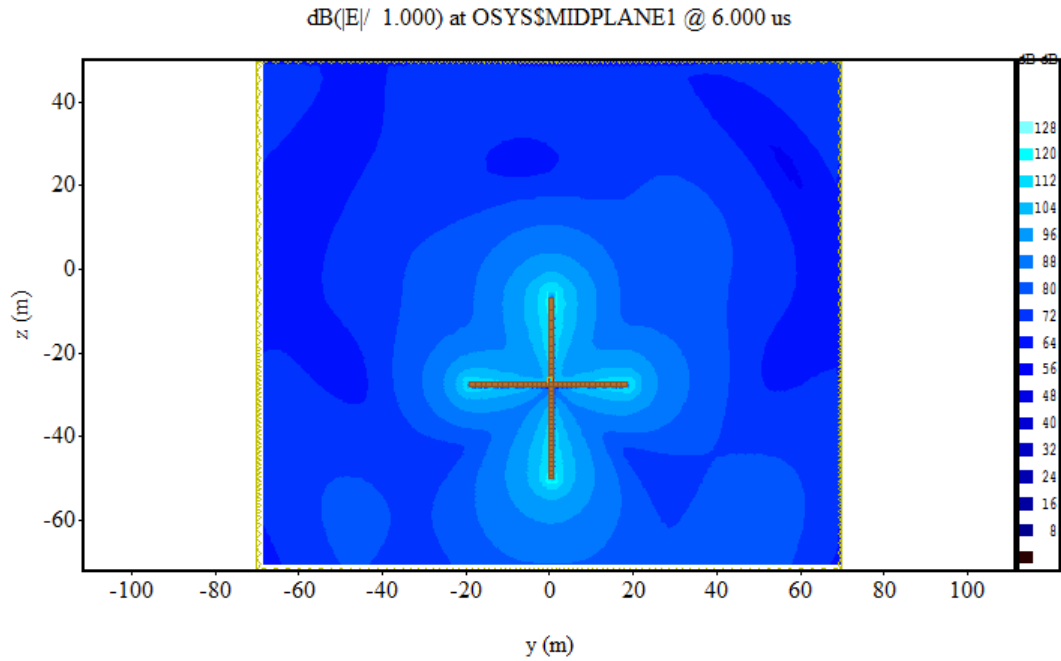
Fig 12. Case H, λ/4 feedline, E magnitude plot.

Finally we look at the λ/4 no ground case (A) with a gap at the top of the feedline. The field is below is weak and the current at the top of the feedline is .84 so there is modest common mode effect.
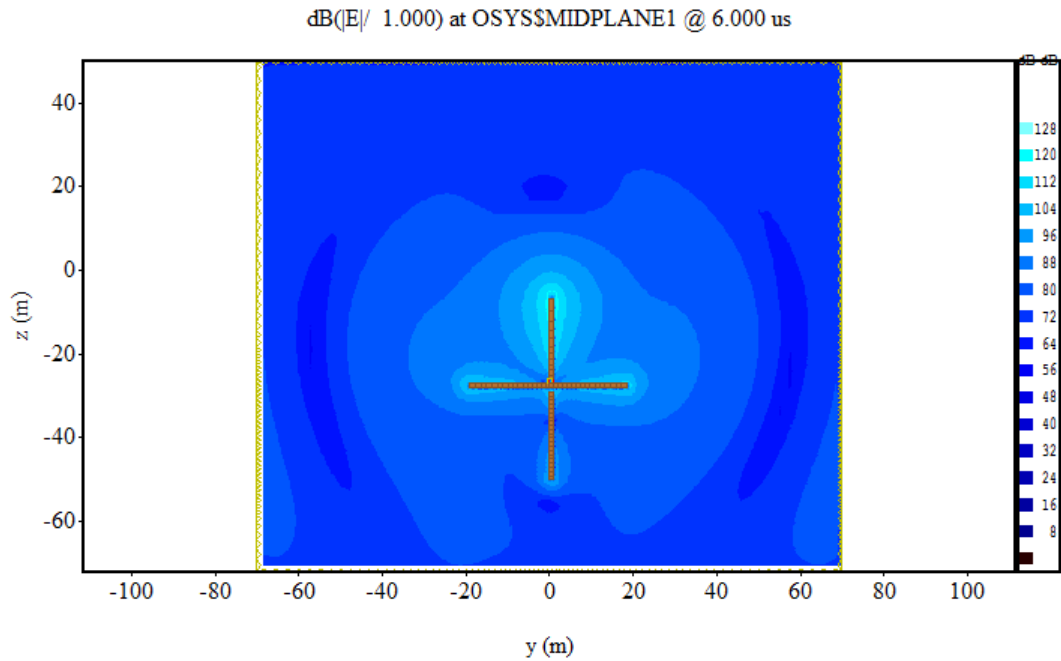

Fig 13. Case A, λ/4 feedline top gap, E magnitude plot.

The table of runs with the currents (mostly without regard to phase) is shown at the end. Beware that the notation is a gap value of 1 means Yes There Is a Gap (of 1 meter).

For final comparison, here is the case (Anofeed) with no feedline showing the E fields and the vector snapshot.
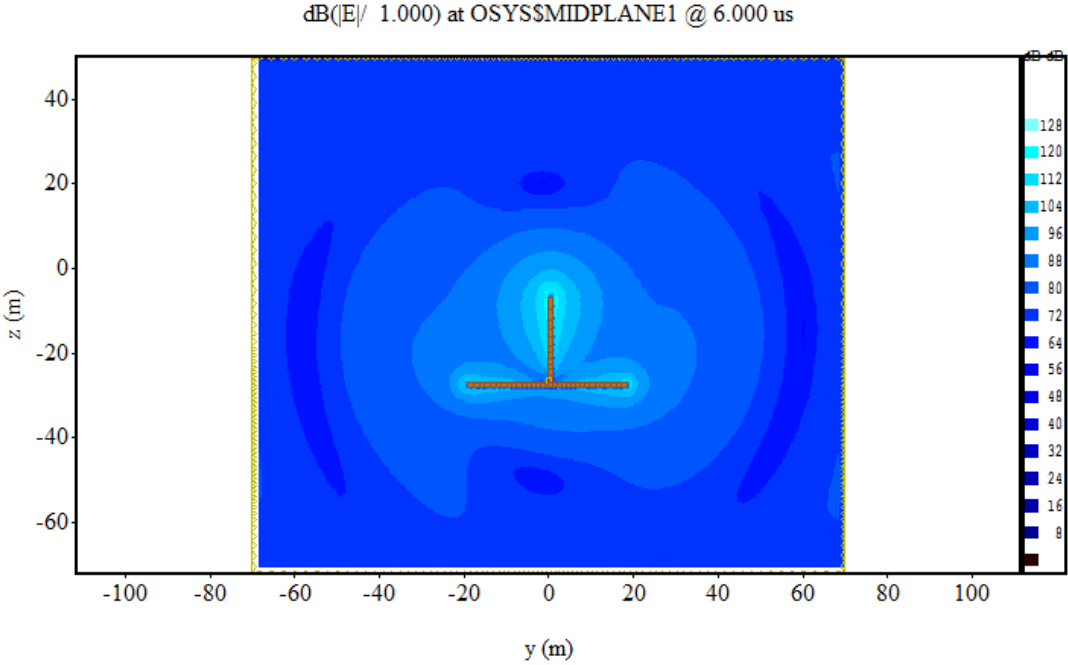

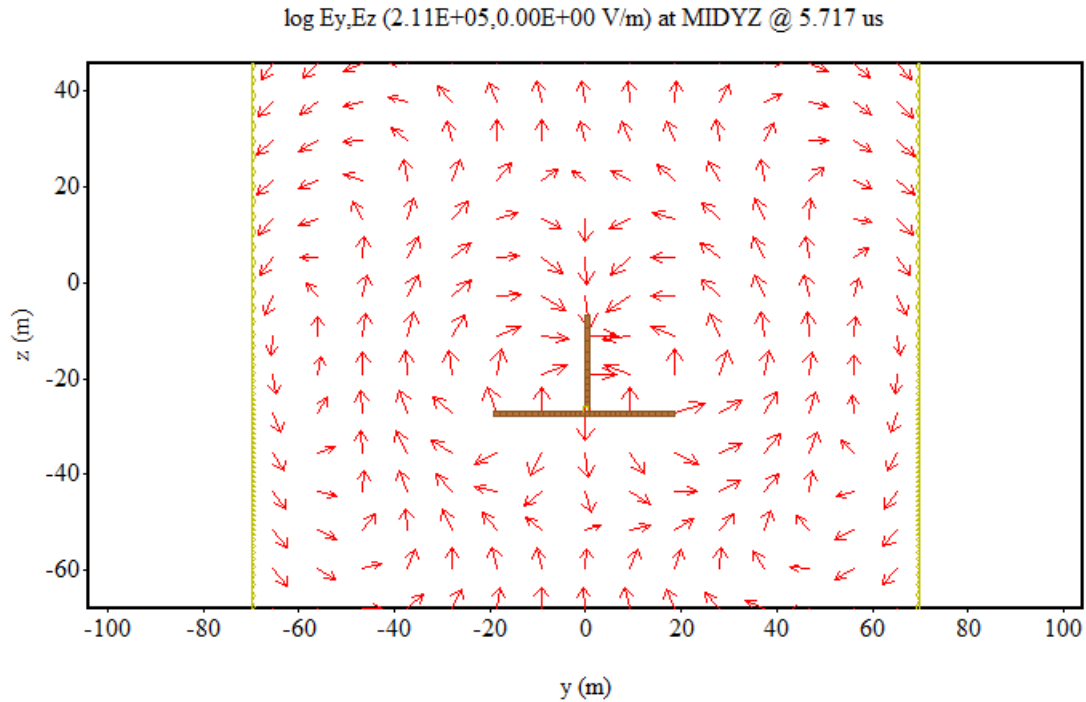Fig 14. Case Anofeed, no feedline, E magnitude plot.

Fig 15. Case Anofeed, no feedline, vector plot.

Note that the vector plot is quite similar to the first one provided in Fig 2 earlier corresponding to the sketch, which did have a feedline. Again there is some vector overlap due to large vectors on the left artificially extending through the antenna conductor

Lengthening a feedline with a top gap

As a final numerical experiment Case A, which has a λ/4 feedline, no ground and a gap at the top of the feedline, was augmented with a longer and longer feed line in increments of about λ/8 (10 meters), up to give an additional ~ 7λ/8, while measuring the currents near the top and bottom of the feedline. It was found that there is a periodicity of about λ/2 of the effects but the feedline currents, shown below, never exceeds about 17% of the antenna current, which is always 10, and the radial currents only fluctuate about 10%. There is evidence of the resonance effects when there was a gap at the top of the feed point in this case, with some variation of the feedline length but never as big as with no top gap. The currents at the top and bottom of the feedline are shown below for lengths measured in approximate wavelengths.
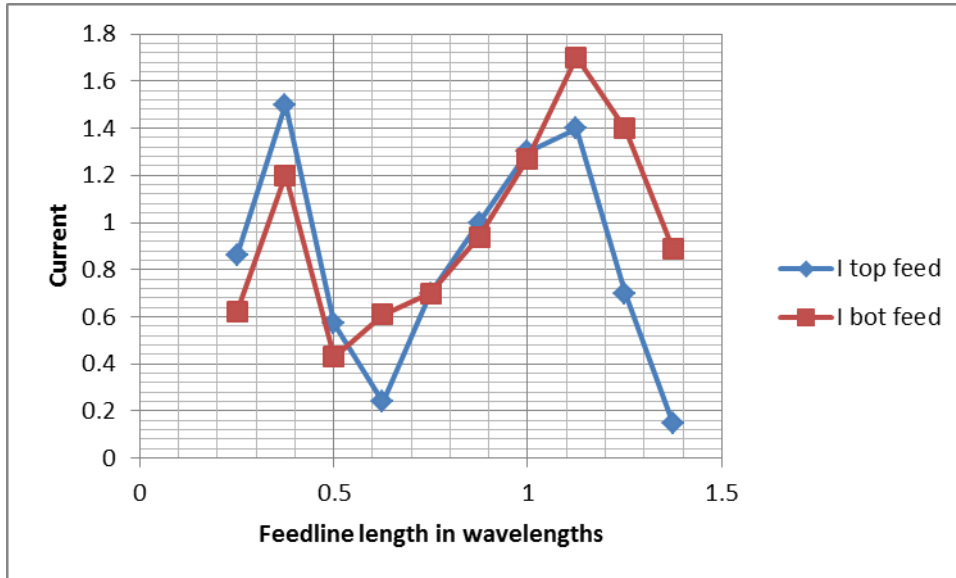
Fig 16. Cases A with extended feedline showing currents bottom (relative to 10 at the antenna base) near the top and bottom of the feedlines.

Also, a series of EZNEC calculations provided by K7HP indicates for no big ground underneath, and even with a gap, worst case lengths can prove significant impacts on the elevation pattern and these correspond to the lengths that give the largest currents in the wire under the GP vertical. These again occur at multiples of $\lambda/2$.

Test of Frequency Dependence using Case A

Just as a test, a final numerical experiment using Case A, with no big Ground, $\lambda/4$ feed line and a top gap was run again at 100X the frequency, 350 MHz with scaled dimensions. The ratios of the various currents are the same and the |E| plot result is given below and it is essentially the same as the prior (A) example.
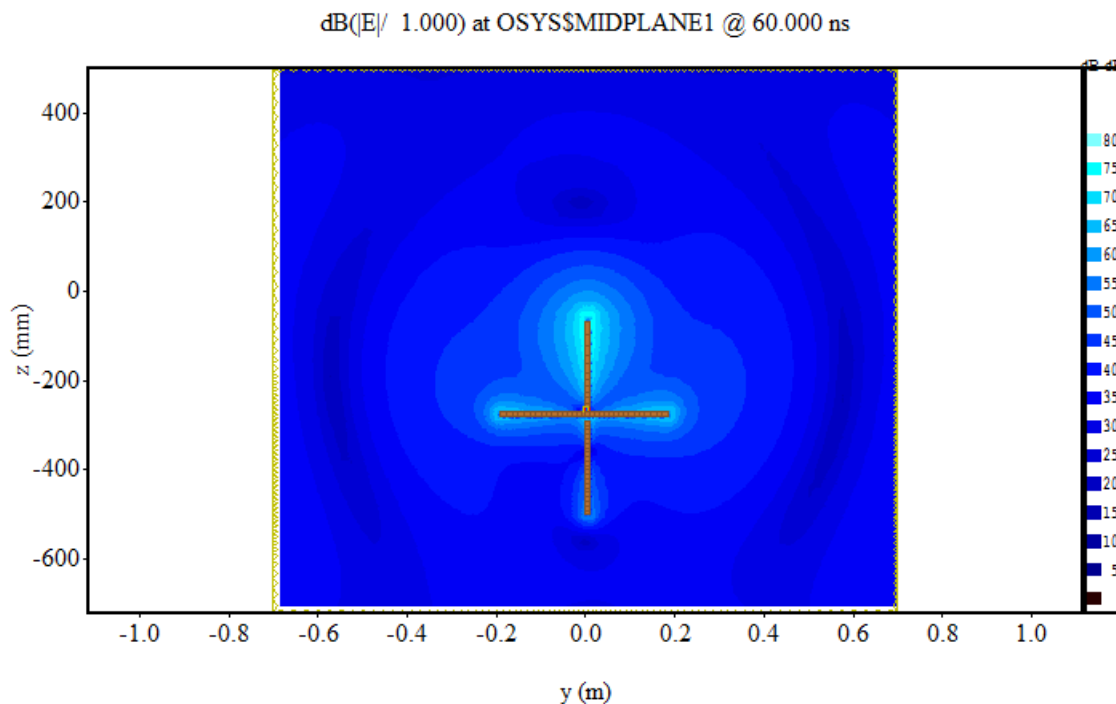
Fig 17. Case Ax100 scaled to 350 MHz, E magnitude plot.

The table of most of the runs is given at the end where the disturbed cases are highlighted in red/orange.

Not too Expansive Conclusions

No case with a gap at the top of the feedline (λ/4 or λ/2) has an obvious issue with common-mode currents based on the antenna and GP radial current changes. This continues to hold true over a substantial range of feedline lengths so it is more than shifting the resonance. However, the K7HP EZNEC calculations suggest it is still possible to significantly impact the elevation pattern even with a gap.

Sketching E fields around antennas needs guidance from real EM solutions, although the uses of this knowledge are far from clear.

Large currents induced in an unconnected wire in the neighborhood of antennas may well not be reasonably interpreted by just thinking of any (non-conductive) displacement currents directly between a gap from the antenna and feedline closest points. Consider a Yagi for example, as mentioned in the article, where the passive element currents are induced by the collective effects of the other fields.

For HF antennas, it seems likely that there may be cases where the length of the unchoked (or poorly choked) coax feedline plays a large (and likely unexpected due to complex environment) role in common-mode current problems. Even for choked coax feedlines (to the extent a gap is equivalent) it is possible that there could be lesser resonant effects due to induced currents on the feedline outer braid in a way

hard to predict, again due to environments. Still this may produce undesired pattern distortions depending on the details.

Table of most runs

Case	Large Gnd	Feedline/?	I ant	I top Feed	Feed Gap?	I bot feed	Bot Gap?	I radial sum	I radial 1	I radial 2
M	1	0.5	10	0.04	1	1	1	10.4	2.6	2.6
B	1	0.5	10	0.72	1	1.5	0	9.8	2.45	2.45
I	1	0.5	10	0.01	0	1.007	1	10.4	2.6	2.6
C	1	0.5	10	9.6	0	-9.6	0	8	2.1	1.9
N	1	0.25	10	1.1	1	1.1	1	9.6	2.2	2.6
E	1	0.25	10	1.1	1	3.8	0	11	2.4	3.1
L	1	0.25	10	4.2	0	2.1	1	14.4	3.2	4
D	1	0.25	10	1.05	0	1.7	0	10.8	2.4	3
P	0	0.5	10	0.36	1	0.89	0	10.6	2.5	2.8
G	0	0.5	10	0.52	0	0.63	0	10	2.5	2.5
A	0	0.25	10	0.84	1	0.6	0	9.6	2.3	2.5
H	0	0.25	10	7.7	0	2.7	0	17.6	4.2	4.6
Anofeed	0	na	10	0.15	na	0.04	na	10.2	2.4	2.7