



Useful Radiation from Compact Antennas: PLATES

By David J. Jefferies

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Many readers of *antenneX* articles are in pursuit of the “holy grail” of electrically small, wideband, efficient antenna structures. In the March 2001 issue ([Useful Radiation from Compact Antennas: LOOPS](#)) we discussed small, multi-turn, tuned loop antennas. This companion article attempts to discuss how we might use short plates to circumvent the physical limits of dimensionally compact antennas, which have low radiation resistance as discussed in the February 2001 issue of *antenneX*, “[Radiation Impedances of Wire and Rod Antennas](#)”

February’s article attempted to explain that as it is the accelerated charge which radiates, the contribution to the electric field at large distances is proportional to the time rate of change of (length times current). More radiation is produced by higher currents, by currents in a longer length of wire (provided it is short compared to a quarter-wavelength), or, for a given antenna structure, by increasing the time rate of change (by putting up the frequency).

ENHANCE PERFORMANCE

In this month’s article a suggestion is made which might enhance the performance of compact antennas, again by lengthening the current-carrying parts of the antenna without enlarging the overall physical dimensions. Also, we can tune the antenna as was discussed in another earlier *antenneX* article ([From The Shack](#) — “Antennas with Area”) so that the current in the radiating structure is many times larger than that supplied by the feed. In this version of “the trick”, instead of running current through multiple turns of a multi-turn loop, we straighten out the turns and place them side by side and feed them in parallel. We might call the former method the “series solution” and this month’s attempt the “parallel solution”.

Of course, once we have placed all the strips of conductor side by side, we can connect them together to each other along their lengths, as there is no sideways current flow. This is functionally equivalent to making a wide plate antenna. Since RF current flows within a “skin depth” of the surface of a conductor, increasing the area of the plates for the same total current flow will reduce the resistive ohmic loss and make the antenna more efficient. Also, because a short antenna has a very high series capacitive reactance $X_c = 1/(2 \pi \text{ frequency capacitance})$, this corresponds to a low physical series capacitance. We might expect the capacitance to increase, and therefore X_c to drop, if we can increase the area of the structure. (We are getting into the domain of “antennas with area” again, of which the CFA and the biplane are two notable examples). Alterna-

tively, we can regard our structure as a kind of patch antenna, where the patch is suspended in free space and not mounted (as is more usual) on a dielectric backing plane.

MODEL IT

It is instructive to run a little NEC2 simulation to see how the driving point impedance of a short dipole antenna varies as the circular-cross-section rods are made fatter. For comparison purposes, we'll take the small loop we considered last month, designed for use on the 80 metre band, and straighten out the turns to get the same total length for the rods. For the reasons discussed in previous articles, we find that when this is done the radiation resistance shoots up (there being no cancellation from current elements as there is on the opposite ends of a diameter of a loop antenna).

Of course, a NEC2 simulation of such a structure may be at the limits of applicability of the software method. However, the trend (as the rods are made fatter) will be evident, even if the numbers are not 100% accurate.

When we do this, using dipole length of 5.34 metres (one turn of the equivalent loop, straightened out), the individual rod length is half of this, 2.67 metres which is about 0.0343 wavelengths. So we might also consider a monopole over a ground plane consisting of a fat cylinder, 2.67 metres long as a possible compact antenna design for 80 metres. In true academic form, this is "left as an exercise for the reader". This is beginning to look like the E-plate of the CFA structure.

In **Table 1** we show (for the dipole version in free space) as a function of the the cylinder diameter, the Q factor, the maximum useable bandwidth in Hz at a carrier frequency of 3.852 MHz, and the parallel resonance resistance presented to the feed. Here, the Q factor is set by the ratio of capacitive reactance to radiation resistance. When we do a series-parallel conversion and tune out the reactance with an inductor, the antenna presents a pure resistance to the feed which is $(Q^2 R_{rad})$. To get this resistance down to match a sensible feed Z_0 , we can tap down on the tuning inductor. However, the Q factor still sets the bandwidth B as $B = \text{frequency}/Q$.

Table 1

Diameter (metres)	Q factor	Bandwidth (Hz)	Resistance presented to feed
0.001	3130	1230	13.30 Meg
0.010	3073	1253	9.10 Meg
0.020	2734	1409	7.00 Meg
0.040	2367	1627	5.10 Meg
0.100	1514	2544	1.80 Meg
0.200	1269	3035	1.20 Meg
0.400	990	3891	0.95 Meg
0.800	697	5527	0.41 Meg

It is clear this arrangement is not good as a practical antenna until the cylinder diameter is over half a metre. The bandwidth is insufficient and the impedance transformation impracticable.

However, there is hope yet. The NEC simulation indicates that a parallel inductance of about 41 microHenries might be used to resonate the 0.80-metre diameter cylinders. Sticking our necks out, we might think that we could slit the cylinder parallel to its axis and open it out into a plate. We therefore have the choice of a fat cylinder antenna, or a wide plate antenna. Since currents which radiate could flow on both surfaces of the plate — but only on the outside of the equivalent cylinder — we might make the corresponding plate of width $(\pi/2)*0.80$ metres or 1.26 metres (126 cms, 49.5 inches). The equivalent series radiation resistance is about an ohm. If we tap the inductor at about 1/37th of its total length to match to a 300-ohm open feed, a power of 100 watts delivered to the antenna will produce a voltage between the plates of $37*\sqrt{100*300} = 6.4$ kV r.m.s. approximately, which is not totally impracticable. And we have a tuned bandwidth of 5.5 kHz which may be sufficient for voice communications.

Just to check that this power isn't going straight into heating up the antenna structure, we can run the NEC2 simulation again for a perfect conductor and the last line in our table above then becomes:

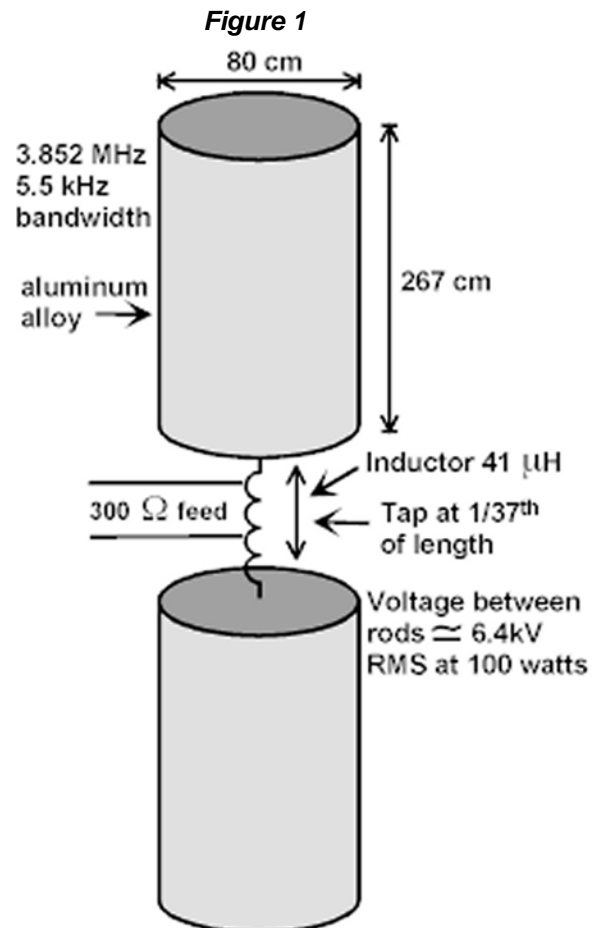
Table 2

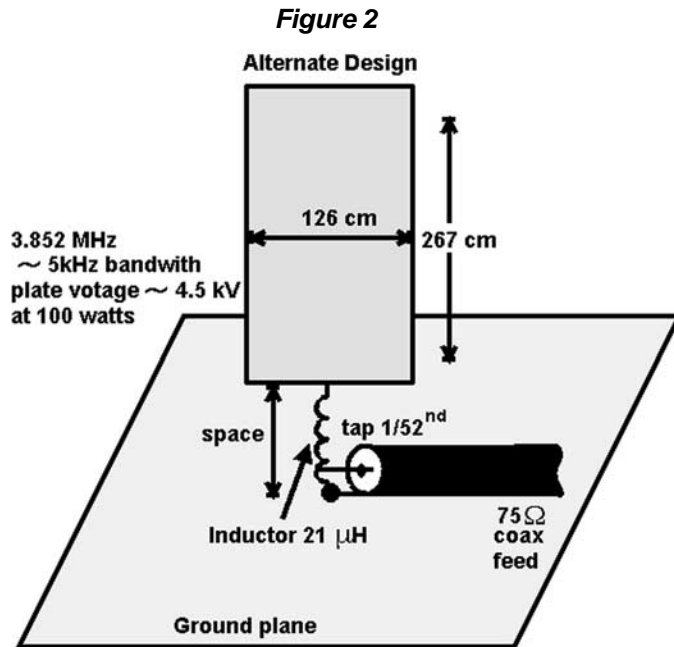
0.800	697	5527	0.41 Meg
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...which is no different; **so the antenna is efficient.**

So, now to practicalities: There are many ways we could implement this design process, so we show just two possibilities. In **Figure 1** we show a dipole cylinder antenna, with a balanced 300-ohm feed tapped symmetrically into an inductor of 41 microHenries. The amount of inductor between the feed points needs to be 1/37th of the total length of the inductor. For a radiated power of 100 watts, the r.m.s. voltage between the dipole cylinders is about 6.4 kV, not impossibly large.

In **Figure 2** we show a flat plate monopole-above-ground-plane antenna with the same calculated effective area for radiation. This one requires a 21 microHenry inductor, with a tap 1/52nd of the way up from the ground plane to feed the centre conductor of an unbalanced 75-ohm coaxial cable feed. For 100 watts of radiated power the voltage between the plate and the ground plane is about 4.5 kV r.m.s., where we have not specified how large a ground plane is needed, but it might have to





be about a wavelength across.

These ideas are not meant as serious constructional practical suggestions, but are offered as an illustration of the kind of antenna that might be invented by following this logic. It is clear, to this author at least, that the CFA broadcast band structures may fall into this category.

WARNINGS

Now let's put in the caveats. The NEC2 simulation, for the fatter rods, used only 7 segments in total. Nevertheless, the current distribution along the rods does look believable. As we fatten the rods further, with the same segmenta-

tion, the distribution breaks up and starts to vary along the length in an oscillatory way, so this sets the limit to which we have taken the NEC. Furthermore, it is not clear that we are allowed to open out the cylinder into a flat plate as suggested, without affecting the numbers. In any case, the numbers are only a very rough guide. Also, the inductor design will take care and thought, as there are large voltages flying around. Neither have we considered the interactions with the ground or with the feed or with other objects within a wavelength of the antenna. All these factors may be expected to affect the measured behaviour. One might expect capacitive coupling to ground and other objects to be much larger for a large-area structure like this, than for the more usual wire antenna, and so the adjacent objects may have much more effect on the antenna performance.

CONCLUSION

However, in conclusion, despite what the pundits say is possible, we have tried to design an efficient small 80-metre antenna with sensible bandwidth and good efficiency, and the design does not look totally impracticable. It may of course be scaled down in size and up in frequency for use on 40 and 20 metres. The useful bandwidth will be twice as much on 40 metres and four times as much on 20 metres. The design relies on accepted standard radiation theory, as implemented by NEC, and therefore invokes no *Deus ex Machina* such as is involved with disinterring the remains of James Clerk Maxwell, for which, no doubt, his ghost will be exceedingly thankful. -30-

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