37 Dovercourt Road, London SE22 8SS

TT

A close look at stub-feeding monoband λ/2 and 5λ/8 verticals ♦ Multi-band verticals ♦ A current regulator designed for controlling the brightness of super-LEDs ♦ Further information on electrically-small transmitting antennas.

STUB-FEEDING λ/2 & 5λ/8 VERTICALS
A recent letter from G3GUB/ AC4UA rekindled an interest in the problems of feeding vertical antennas longer than the traditional quarter-wave monopole/ground-plane. Bryan needed help. He wrote: "I am off to Panama to help an American lady sailor-ham tweak her communications for a trans-Pacific voyage. ATUs don't like the salt-laden atmosphere (crud on capacitor plates/roller-tuning!). Last year I installed for her a 42ft (5λ/8 on 14MHz) with a chain dangling into the sea as 'earth'. It works well, but I recall that somewhere in 'TT' was a system using a coax-stub and tapping point that gave a 50Ω match and which took account of the velocity factor of the coax cable. Can you tell me what issue?"

I must admit that I had absolutely no recollection of the item and came near to giving up the search. Perhaps not surprising as, when finally located, it proved to have been a very short item in an issue exactly 33 years ago: May 1971, p323. It read as follows: "Many references have been made in 'TT' and elsewhere to the attractive vertical radiation pattern of the five-eighth-wave vertical monopole. This works out at about 41ft overall and is complete with a base insulator. This suggests that there could be plenty of interest in a simple coaxial-line matching transformer (stub) described in *QST* (January 1971) by Robert Earl, W1DRV, specifically for feeding a 14MHz five-eighth-wave vertical from 50Ω coax: see **Fig 1**. W1DRV based his design on an article by Pete Czerwinski, W2JYJ (*QST,* June 1961), who used a coaxial-line transformer to feed a half-wave 'beer-can' vertical for 14MHz"

Delving further, I traced the original *QST* references quoted above. That of W1DRV turned out to be a short letter in the 'Technical Correspondence' column. He noted that W0JF had reminded us of the useful low-angle radiation of the 5λ/8 vertical antenna in the August, 1970 *QST* - quoted very briefly in 'TT' December 1970, including **Fig 2** providing a summary of matching conditions for base-fed verticals of varying lengths. W1DRV felt that the W2JYJ and W0JF articles went well together as the basis for the coax stub design shown in Fig 1.

FIG 1 © RADCOM 149

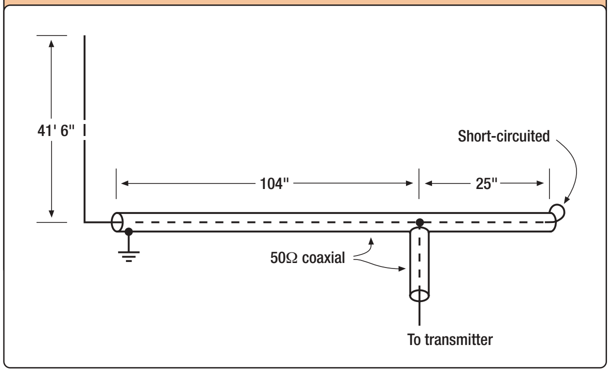


Fig 1
Use of coax-line (stub) impedance transformer to voltage-feed a 14MHz 5λ/8 vertical antenna as suggested by W1DRV in 1971, based on an earlier article by W2JTJ (see text). A similar arrangement could be used to feed other voltage-fed antennas such as the 'inverted ground plane' (see Fig 5(c)).

Fig 2
Summary of basic matching requirements for mono-band verticals as explained by W0JF in 1970.

He added: "My hastily-constructed 5/8-wave vertical antenna (inspired by W0JF's results) consists of a supporting structure made from sections of 2 x 2in lumber upon which four lengths of 300Ω TV ribbon are affixed. Each section of ribbon line is 41ft 6in long. A length of this line is attached to each side surface of the 2 x 2 support mast, then the ends (top and bottom) of all four line sections are connected in parallel to form a single [fat] vertical conductor. The coax line dimensions are near those of W2JTJ, and are shown in Fig 1. The VSWR varies from a flicker of reflected power at 14,000kHz to 1.5:1 at 14,350kHz. (My next task is to get that lowest-VSWR point shifted to 14,275kHz). The whole thing is leaning against a tree, almost vertical, and seems to work well."

The earlier *QST* article by W2JTJ gave a more detailed explanation of this simple coax-transformer matching device, showing how the tapping point could be accurately determined for the lowest possible VSWR. **Fig 3** shows how a shorted quarter-wavelength of transmission line is equivalent to a parallel-tuned circuit. A match is obtained in either case by connecting the feed-line at a tap point. Note use of T-connector once the tapping point for lowest VSWR at the desired frequency has been found. For coax line, the velocity factor of the cable (typically 0.66) is used to obtain the length of the shorted line. W2JTJ, for a design frequency of 14,100kHz gives the length needed as 11ft 6in. If your radiator is not precisely a half-wave long (and it need not be), it will be either capacitive or inductive, depending on whether it is slightly shorter or longer, respectively, at the design frequency. This is of no consequence, for the resultant susceptance of the stub and the radiator will automatically be cancelled during the tuning procedure. However the length of the coax section should be made longer to allow for this.

For adjustment, W2JTJ advised the use of a GDO and VSWR bridge: "First, solder the inner conductor (point A) of the coaxial transformer RG-58 to the radiator, and the outer conductor (point B) to the ground system. Now measure 26in from the shorted end and remove a half-inch-wide band of the vinyl jacket. Spread the braid carefully to expose a spot on the polyethylene inner insulation. Solder a sewing needle to the exposed end of the inner conductor of your feed coax coming from the transmitter. Insert this needle through the prepared opening in the exposed braid of the stub so that it makes contact with the inner conductor. Now spot-solder the feed-

FIG 2 © RADCOM 150

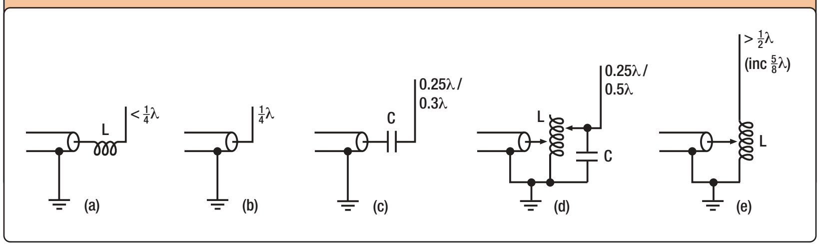


FIG 3 © RADCOM 151

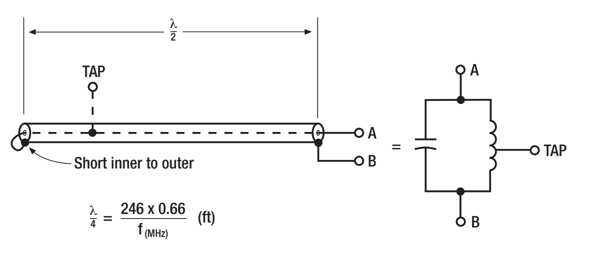


Fig 3
A shorted quarter-wavelength of transmission line (coaxial, open- or twin-wire) is electrically equivalent to a parallel tuned circuit. An impedance match can be obtained by tapping a 50Ω or 300Ω feeder at a suitable point (see text).

Fig 4
Dimensions suggested by W1DRV for a 14MHz 5λ/8 14MHz antenna.

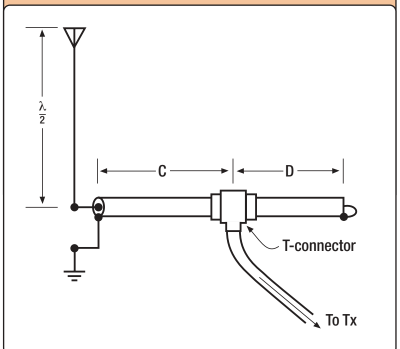
Fig 5
Showing alternative use of open-wire transmission line as impedance-matching transformer for voltage-fed antennas such as half-wave verticals or 'inverted ground-planes'

line coax and stub braids together. Excite the line from the transmitter with the GDO and read the VSWR bridge.

"If you are lucky, the reading will be close to a null (no reflected voltage). If not, then make an adjustment on the length of the coaxial transformer by inserting a second needle approximately one inch from the shorted end, making sure that it is shorting the braid to the inner conductor. Repeat this adjustment, moving the short an inch at a time, as long as it improves the bridge null. Then make a similar adjustment on the location of the tap by moving the first needle approximately 3in either way, after baring two new spots. This will show in which direction the tap should be moved; the final adjustment can be made by trying the tap at smaller intervals.

"When a bridge null is obtained and the GDO dips best at the design frequency, carefully measure the dimensions C and D of **Fig 4**, and make up a new cable using a coax T-connector at the tap point."

FIG 4 © RADCOM 152



It should be appreciated that there will be high RF voltage across the coax cable towards the radiator end, but W1JTJ reported that "There was no sign of voltage arc-over using a DX-100 with 175W input. For higher power, it is recommended that RG-8/U be used. When the coax transformer is completed, the open ends should be sealed with plastic tap; then it can be wrapped into a coil around the base of the antenna." His 'beer-can' radiator is mounted on an insulated base and is virtually at ground level. There will be high RF voltages over the first few feet of the radiator that could be a hazard to children and animals etc – precautions should be taken to prevent accidental touching of the radiator.

It should be appreciated that virtually any length of radiator (voltage- or current-fed) can be accommodated by this form of 'resonant-line' coaxial-transformer system or by using the line in conjunction with a 'Zepp-type' ATU. **Fig 5** shows three ways of using open-wire feeder stubs. Note that the bandwidth of any vertical or horizontal element is increased by the use of a tubular mast or multi-wire element, as with the 'beer-can', or two or four twin-wires as described above.

MULTI-BAND VERTICALS

The antennas described above, using tapped coaxial line matching transformers, are essentially monoband systems. However several multiband antenna systems have been described in 'TT' and can be found in the *Antenna Topics* collection (RSGB, 2002). An ingenious use of a 13m vertical element for 3.5, 7 and 14MHz, from March 1971 (*AT,* p45) originated by LA1EI and using three feeders, is shown in **Fig 6.** This represents a 5λ/8 vertical on 14MHz, but an electrically shorter, but still effective, vertical antenna on 3.5 and 7MHz. It uses loaded matching RG-8/U sections to allow the same radiator to be used on 3.5 and 7MHz with gamma-matching feed on 3.5MHz. C is about 68pF and L about 2.8mH. If n is an even number, the impedance is 75Ω at 3.5MHz, 34Ω at 7MHz and 75Ω at 14MHz.

A triband vertical, originated by Frank Regier, OD5CG (who in 1984 was kidnapped and held hostage for several weeks in Beirut), appeared in 'TT' (April 1970 and *AT,* p33) using 300Ω twin feeder line suitable for 14, 21 and 28MHz, **Fig 7(a)**. The radiator (A) comprises 22ft of 300Ω feeder shorted at each end. The ground plane (B) comprises quarter-wave radials for each band (12 wires in all). The matching section C is 27.8ft of 300Ω feeder. The reactance matching section is shown in detail in **Fig 7(b)**, the coil L1 comprising 7 turns of No 16 wire 1in in diameter and 1in winding length. It can be set up using only a GDO. C1 is adjusted so that L1-C1 resonates at 35.83MHz. Then C2 is temporarily connected in parallel with L1-C1 and set so that the circuit now resonates at 21.37MHz.

The matching section comprises some 27.8ft of 300Ω, with 22ft of this type of feeder also used for the radiator, with the ends short-circuited. The matching section assumes a cable velocity factor of 0.82, and a slightly different length would be needed with cables having a significantly different velocity factor. The ground-plane comprises four radials each consisting of λ/4 of wire for each of the three bands (12 wires in all). Further details in *QST* (December 1969) or 'TT' or *AT* as cited above.

REGULATOR FOR SUPER-LEDS

À propos of my comments on the new ranges of bright LEDs ('TT' November, 2003, p90) it was interesting to see an item 'Super-LED Regulator', in the 'Circuit Ideas' feature of *Electronics World,* September 2003, p22. This drew attention to the

FIG 5 © RADCOM 153

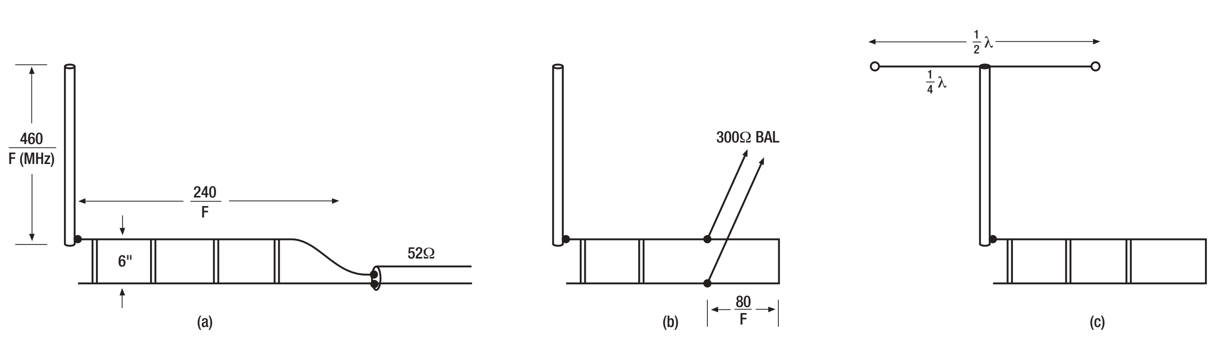
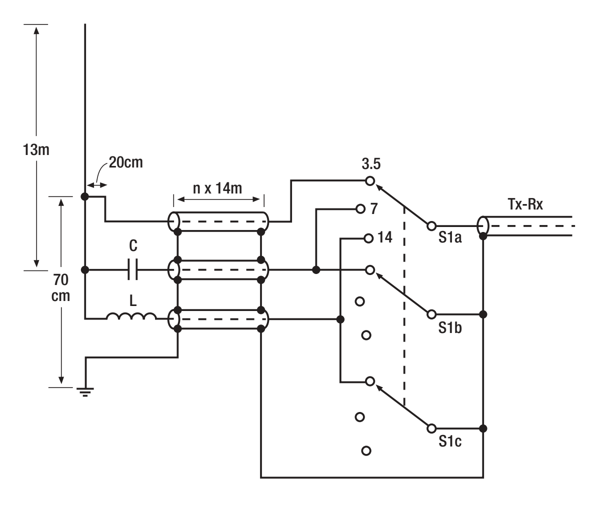


FIG 6 © RADCOM 154



Luxeon range of high-brightness LEDs from Lumileds in California. Available in various colours, the white Star/O variant includes optics to give a forward beam of about 10° making it ideal for a powerful torch that can be dimmed to extend battery life. Maximum device current is 350mA at 3.4V. There is a built-in heat sink that requires plenty of fresh air or conductive cooling to avoid damage due to overheating.

Fig 8 shows an arrangement that provides a variable regulated current enabling the brightness of the Luxeon to be set from 'off' to 'full on', and will keep the LED bright as the battery voltage beings to fall. With integral optics providing a 10° beam, it provides an excellent torch when powered by three NiMH AA batteries. The circuit uses an LM10 IC op-amp which, when wired as shown, provides 200mV at pin 1. The 4.7kΩ resistor and 1kΩ pot divides the 200mV to 0-35mV fed to the non-inverting input of IC1b. As a result of feedback, the voltage across the 0.1Ω resistor matches the 0.35mV from the reference section, enabling the current through the LED to be varied from 0 to 350mA. As the battery voltage drops, the voltage at pin 6 rises and the 'battery low' LED functions. It is claimed that, run on three NiMH cells, the circuit is over 90% efficient at full power and tops 80% for most of the range. Although current is under 1mA at minimum brightness an on-off switch should be fitted. Choice of the ZTX692B transistor is fairly critical since the device must have a low-saturation voltage at low base current since pin 6 of the LM10 cannot supply much current and there is only 200mV headroom between the 3.6V NiMH battery voltage and the 3.4V Luxeon voltage

The Luxeon device is available in small quantities in the UK through www.futureelectronics.com See also www.luxeonstar.com

Fig 7
The OD5CG triband vertical antenna for 14, 21 and 28MHz.

Fig 8
Current regulator designed for use with the Luxeon super-LED.

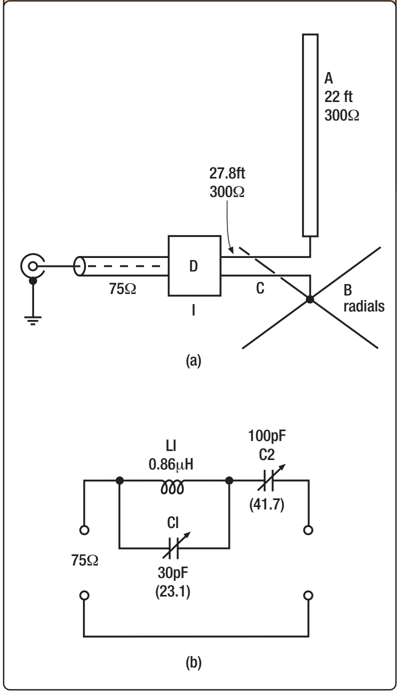
ELECTRICALLY-SMALL TRANSMITTING ANTENNAS

In view of the spectacular claims for the efficiency of the new generations of electrically-small transmitting antennas such as the CFA, CFL, EH and the small loops investigated by Prof Mike Underhill, G3LHZ, and his student Marc Harper. I would emphasise that there is, for a critic, a difference in commenting on these projects. The first three are being exploited commercially and criticism incurs the risk of trade libel. G3LHZ's work is in pursuit of scientific knowledge and has been presented at professional conferences for discussion by (sceptical) professional peers as well as thrown open to discussion in professional as well as amateur journals.

But not only my eyes were raised on seeing the Arno Elettronica advert (facing the opening page of the March 'TT') claiming >95% efficiency for their 3.5MHz and 1.8MHz E/H models. I am not in a position personally to comment on these claims, but would draw attention to a long, detailed Test Report *Investigation of the Far-Field Radiation Gain Pattern of the 20-metre Backpacker EH Antenna*, by Adam MacDonald, N1GX and Kevin Prosser, WA1ZEB (March 2003), and an additional Test Report on continued investigation of this antenna by Adam MacDonald, N1GX.

These two very professional reports, running to nearly 50 pages, were found on a private website, presumably that of N1GX and brought to my notice by Dr Brian Austin, G0GSF. As he comments, "These reports certainly represent some very comprehensive experimental [expert] work on the EH antenna and should lay to rest the mythology ...." While the reports cover only the 14MHz Backpacker Antenna, mounted on a short PVC mast with resonant sloping ground-plane radials, the authors state: "It is expected that the results obtained from the 20m 'Backpacker' version of the EH antenna can be easily extended to other similar short-dipole EH antenna arrangements".

FIG 7 © RADCOM 155



To quote briefly from the summary of the initial Test Report: "... Baseline test data were collected by feeding the test antenna with a very short length of coaxial feed-line. Additional data were collected by feeding the test antenna with approximately one physical wavelength (70ft) of coaxial feed-line... Far field radiation... fed by a very short length of coaxial cable was measured at an average 28dB loss referred to the azimuth radiation pattern of the quarter-wave reference antenna... Fed by 70ft of [sloping] coaxial feed-line was measured at between approximately 12 and 28dB of loss relative to the reference antenna, dependent on the azimuth of the [car-mounted] measuring receiver. Inclusion of the feed-line... caused significant increase in the

FIG 8 © RADCOM 056

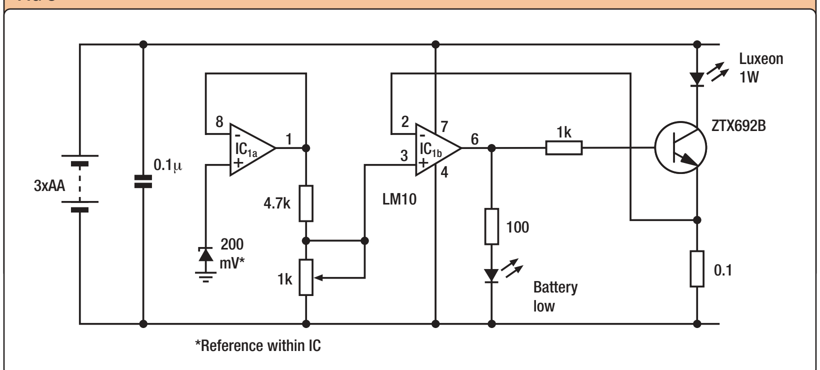


FIG 9 © RADCOM 157

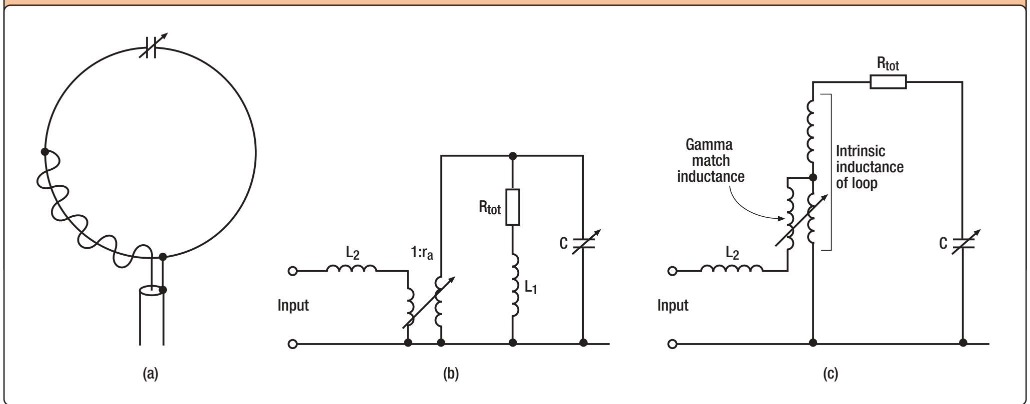


Fig 9
(a) Physical realisation of the Underhill/Harper small loop antenna. (b) Idealised electrical equivalent as used in their papers. (c) 'Real' equivalent circuit as propounded by G3UUR.

measured far-field pattern received power at all but one point along the perimeter of a circular measurement range. No data were collected that suggest that the test antenna obeyed physical laws other than those properties well described in the common body of experimental and theoretical electromagnetic literature."

To quote from the summary of the second Test Report: "The far-field radiation [when] fed by a moderate length of coaxial feed-line was compared to a similar-height reactively-matched monopole reference antenna… Far-field received power measurement data were collected for both the reference and test antenna over a total of 23 test positions, six of which were locations which provided an opportunity to explore the elevated gain pattern at angles up to approximately 21° above the horizon… Far-field radiation of the small test antenna fed by an 11ft length of coaxial cable was measured and found to be essentially indistinguishable from the far-field gain pattern of a loaded monopole reference antenna of the same overall height."

To turn to the Underhill/Harper controversy: G3LHZ asked me to forward to Dave Gordon-Smith, G3UUR (see brief comment in the April 'TT') a copy of one of the two papers presented on their work at the IEE HF Radio 2003 Conference at Bath University: 'The Estimation and Measurement of the Efficiency and Effectiveness of Small Antennas in an Environment'.

G3UUR has since provided comments on this paper and also on papers found on Marc Harper's web pages on the University of Surrey's website. He writes:

"One of the papers I found there discusses the equivalent circuit of the small loop arrangement that has been used for the research that has provoked the storm of controversy in 'TT'. The matching method used by Harper and Underhill to excite their loop (see **Fig 9(a)**) is a bizarre and messy arrangement, which I know will severely distort the characteristics of the loop as seen by the transmitter. The main problem with a gamma match approach is that it cancels some of the self-inductance of the loop. In this case, it cancels quite a lot because it covers so much of the loop circumference and couples so well to the high-*Q* loop. The loss of the loop, of course, remains the same as if it had not had this inductance cancelled, and therefore the *Q* appears to the outside world as if it is lower than the real intrinsic *Q* of the loop alone. Their equivalent circuit, **Fig 9(b)**, is an idealised version; the real equivalent circuit is shown in **Fig 9(c)**.

"The net effect of operating the loop like this is that the apparent *Q* of the loop, as seen by the transmitter, will be very much lower than the natural *Q* of the loop. This explains the exaggerated values of radiation resistance measured by them. Only a truly 'clean' and 'transparent' magnetic method of coupling to the loop will give a true representation of the behaviour of the loop at the transmitter. Their arrangement is not such a method!

"So, whereas I had suspicions about G3LHZ's claims of high intrinsic efficiency for small transmitting loops before, now I have no doubt that he is wrong, and I know why! With regard to his theoretical calculations of new limits to the minimum *Q* of small antennas, I reject these totally, because they are based on a mode that cannot be excited in a small loop or short folded dipole. The basic physical principles of induction would not allow the currents in the upper and lower arms of a short folded dipole to be in phase as claimed in their paper. Only physical size would allow enough phase shift for the standing waves on a pair of parallel conductors to attain the in-phase condition."

Although not based on personal experience but purely on comments by and reported experiences of others, including the above, I would offer the following views:

The transmitting loop with the dimensions and suitable construction can, in certain circumstances, form a useful antenna for amateurs in situations where space is severely restricted. In particular, a mobile-mounted or loop at low height can outperform a whip antenna (whether loaded or a quarter-wave monopole) for NVIS/medium-distance operation because of the vertical null of whip/vertical antennas

There is no convincing evidence that the radiation efficiency of a small tuned loop, the EH or CFA antenna, contravenes the established theory of electrically-small antennas. With dimensions of only a small fraction of a wavelength, efficiency is most unlikely to exceed about 15 to 20% although, when located at a height, in clear surroundings above good earth conductivity, the performance may prove entirely satisfactory. Bandwidth will be narrow and the antenna needs to be carefully retuned (remotely) when the frequency is changed. As G3LHZ emphasises, all antennas are only as good as their environments. Height and size matter! But remember that even an antenna with a radiation efficiency of less than 5% can still be satisfactory over some NVIS paths.

Bandwidth is dependent on the working *Q*. This will usually be significantly lower than the intrinsic *Q* of the element as a consequence of the matching/phasing arrangements as in the CFL, EH and, as outlined by G3UUR above, apparently the G3LHZ antennas. This seems to result in an apparent but illusory violation of the Chu-Wheeler, etc formulae.

For all antennas, and particularly loops, near-field measurements can be highly misleading. To be convincing, HF far-field measurements need to be expertly planned and implemented. To be entirely convincing they need to be based on measurements taken at a number of surrounding (azimuth) and overhead (elevation) points. The tests conducted by N1GX and WA1ZEB (see above) are probably as reliable as possible without flying a field-strength meter in a plane, helicopter, or balloon.

However, the single- and multi-turn loop undoubtedly still offers a useful field for further experimentation. G3LHZ should be encouraged to continue, but to reconsider his >90% claims. For those investing in commercial products, as always, *caveat emptor.* ♦