Antennas from co-ax

Antennas built from coaxial cable are easy to implement, can be matched using the same coaxial cable wired as baluns and give a good compromise between gain and size. Dominic DiMario explains.

The type and number of designs concerning antennas and related components is bewildering. Yet I get the impression that there is still a lot to discover, experiment and field test – especially now that computers provide a means of optimising complex antenna designs.

Using coaxial cable as part of the radiating element of an antenna goes back many decades and several designs have been proposed.[1] The approach used here is to devise a dipole where the matching stub, instead of being hidden somewhere, becomes an integral part of the radiating element.

I chose citizens'-band (cb) equipment to experiment with because it can be easily found and it is relatively cheap. Also, the mechanical construction of the relevant antenna is not critical, although the size can be a problem on occasions.

Figure 1 shoes the basic approach. The stub is a short-circuited length $\ell_1=(\lambda/4)\times P$ of 50Ω coaxial cable, shorted at one end. The propagation speed factor of the cable is represented by P. This factor is 0.665 for standard solid dielectric (polyethylene) and 0.82 for the foamy type dielectric (usually polyethylene/air).

The non-coaxial part of the antenna is made with a 2mm solid copper electric cable cut to a length $\ell_2=(\lambda/4)\times 0.96$ to compensate for the proximity effect.

Although I found this antenna satisfactory when used for receiving, it had a relatively high standing-wave ratio when used in transmit mode. There are two evident drawbacks: first there is a mismatch between the 50Ω impedance of the cable and the 73Ω of the antenna. Secondly, the feed line is unbalanced while the antenna requires a balanced feed.

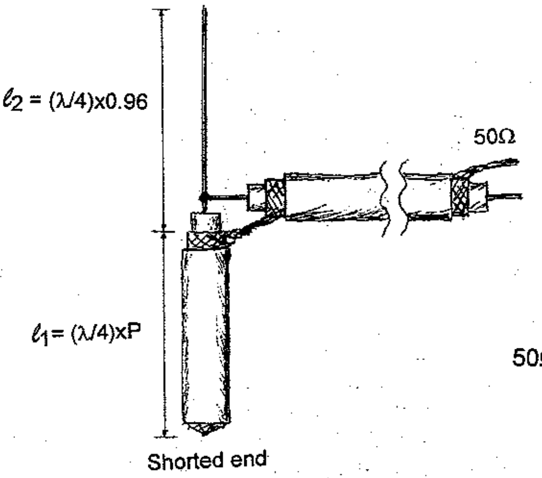

Fig. 1. In this coaxial cable antenna, the matching stub is actually half the radiating dipole. Physical length of the coaxial portion depends on the propagation speed and the frequency of operation. Unbalanced feed and the impedance mismatch limit the performance of this antenna. P is 0.665 for a solid dielectric cable.

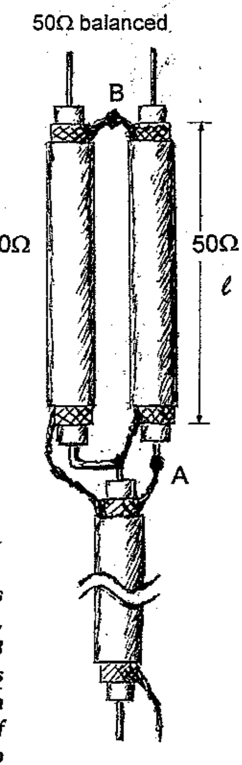

Fig. 2. When fed with a 50Ω coaxial cable, this transmission line transformer will have a 1:1 ratio, from 50Ω unbalanced to 50Ω balanced. Point A and B could be connected together. Length ℓ is always (λ/4)×P. This type of balun is effective only for a limited band around the calculated frequency. If broadband baluns are required it is better to resort to toroidal transformers.

Solving the mis-match

One quick way to solve the mismatch problem is to connect a standard 50Ω car antenna intended for cb use in place of the non-coaxial portion of the antenna.

Under normal circumstances a ground plane is required, and the car body does just that. But with the coaxial solution it is possible to install a car antenna in an apartment or under the roof without the need of a ground plane. Eventually it worked very well, although the actual length had to be slightly shortened.

The second problem is solved by adding a balun which, believe it or not, uses coaxial cable only. This balun's design, **Fig. 2**, is often found in literature[2] and it is always shown as a 4:1 or 1:4 transmission line transformer.

But if the coaxial cables involved have all the same impedance, 50Ω in our case, there is no impedance transformation. Only an easy to make 1:1 balun is needed with practically no losses and perfect matching.

It is worth mentioning that points A and B are at the same potential so they can be connected together thus getting a more compact balun, **Fig. 3**. Eventually the complete antenna was wired as in **Fig. 4**.

It can be placed horizontally or vertically. The standing-wave ratio is 1:1 at the band centre. Bandwidth depends on the length of the antenna in use: the longer the antenna the wider the bandwidth. With a 1.1m cb car antenna, the standing-wave ratio was 1:1.8 at ±200kHz with respect to the centre frequency of 27.185MHz.

Working at other frequencies

This set up should work fine also at other frequencies as the design can be scaled up to the low uhf range. Operation at a higher frequency could be critical due to mechanical tolerance. I made no attempt was made to apply this design at uhf.

An alternative solution to the car antenna is to use straight 2mm electric wire slightly longer than $\lambda/4$, ℓ_2=2.97m for the cb frequency of 27.185MHz, **Fig. 5**. At this length the resistive part of the antenna is 50Ω but there is also an inductive part matched by shortening the coaxial portion, now reduced to 1.32m. This gives an overall length of 4.29m.

Although it is not clear at this point if this antenna is to be considered as a matched $\lambda/4$ or an off-centre fed dipole,[3] it works quite well in practice. It has a much wider bandwidth than the car antenna mentioned earlier. It is also less critical when it comes to make the final length adjustment which is influenced by the surroundings and distance from the ground.

The suggestion here is to substitute the end of the wire with a telescopic antenna and adjust its length until the lowest standing-wave ratio is attained. It should be 1. Next solder an equal length of 2mm wire in place of the telescopic antenna and the construction is over.

Admittedly, the size of this antenna, at least for cb frequencies, does not make it very handy. Its best location could be horizontally under a roof, on a balcony or between trees, national regulations permitting.

Radio and television reception

This design is scalable to higher frequency ranges. I tested it at vhf receiving fm broadcast radio and also tried receiving a television channel transmitting at 220MHz in a fringe area.

Receiving the television channel, the result was compara-

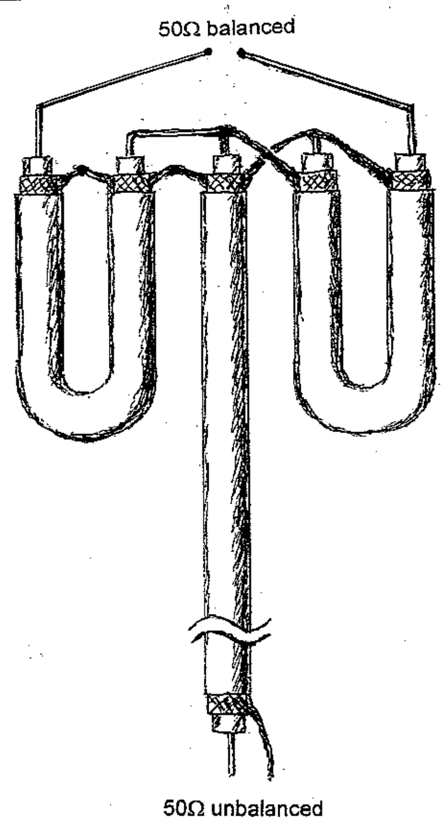

Fig. 3. This short balun is obtained by connecting A and B of Fig. 2. There is no difference in implementing the long or the short balun. It is just a matter of practical convenience with respect to the frequency of operation and grounding requirements.

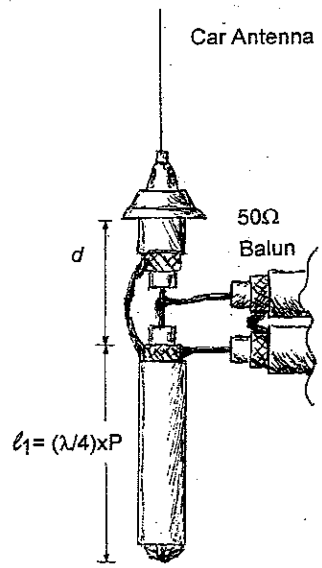

Fig. 4. CB car antenna can be part of a dipole by means of a radiating stub. Distance d should be kept as short as possible as any additional length has to be removed from the total length of the antenna that will be unavoidably shortened. Perfect tuning is critical and any trimming should be accomplished with the antenna already in its final place.

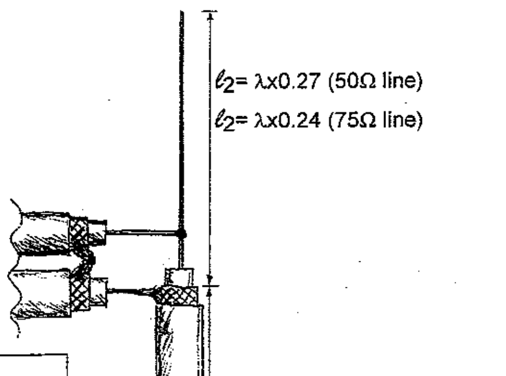

Fig. 5. An antenna longer than λ/4 could be used instead of the car antenna in order to match the 50Ω feed line. This solution has given the best performance, although its overall length of 4.29m in the Citizen Band may pose some problems regarding its physical installation. This is a scalable solution right up to uhf and has given good results also as a receiving tv antenna over a limited frequency range.

Table 1. Segment length of Fig. 5 in millimetres. The vhf television channel is located at 220MHz. The cb antenna is made with 50Ω coaxial cable with solid dielectric while the television and fm radio antennas – including baluns – are made with standard 75Ω tv coaxial cable cable with foam type dielectric.

	ℓ_1	ℓ_2	ℓ_2 dia.	Balun length ℓ
CB	1320	2970 (2)	2	1830
FM	630	730 (2)	2	630
VHF tv	280	320 (1)	1	280
UHF tv	90	150 (1)	1	110

ble to a four-element Yagi antenna. This is not surprising when you consider that a television Yagi is designed to cover a wide frequency range while this coaxial antenna is designed for a specific frequency only.

This solution is best suited where space is limited, as in the case of portable television sets. It will give an improved performance with respect to the existing vhf antenna. Of course, the length of each section must be adjusted for the frequency in use if it is different from 220MHz.

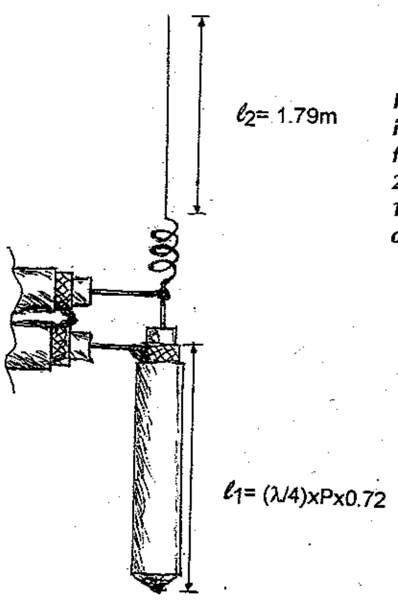

Fig. 6. A shorter antenna is feasible if a coil is added near the dipole feed point. 17 turns of insulated 2mm wire are closely wound on a 17mm form. The total length is now only 3.19m at f=27.185MHz.

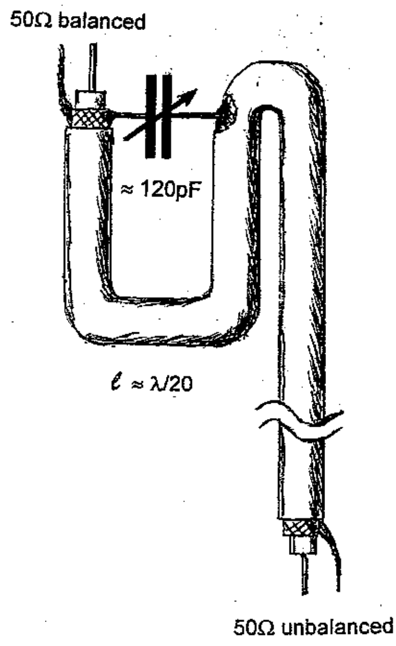

Fig. 7. Variable balancing unit. The capacitor is part of a tuned circuit where a length of the coaxial cable, typically around λ/20 corresponding to a length of 0.55m in the citizens' band, represents the inductance. There is little improvement with respect to a standard balun and its best use could be as a variable splitter. The capacitance, measured at 120pF, could be substituted by a silvered mica capacitor once its exact value is known.

Useful for television?

I attempted to design a coaxial antenna for receiving uhf television channels: due to the large bandwidth required, the segments were cut according to different frequencies and the deliberate mismatch helps to cover a wider band.

In the uhf and vhf range, the line between the antenna and the receiver is a standard 75Ω coaxial cable. This means that the mismatch with the antenna is minimal. It does not require any additional adjustment but the length of the segments is again different with respect to the design intended for cb use, **Table 1**.

If the antenna of Fig. 5 is found to be a little too long for the specific frequency in use, it is always possible to shorten it by installing a coil at the feed point of the antenna, **Fig. 6**. This solution is just as good as the one without coil although a narrowing of the bandwidth has been observed. Also, of course, you have a more complicated construction due to the presence of the coil. Efficiency will be lower because of the additional losses in the coil.

A question of balance

The suggested designs require a balanced feed. But how balanced?

The devised balun gives a perfect balance but I suspected that if a balun with a *variable* balancing could be connected in the circuit it would be possible to compensate for any antenna residual unbalance and improve performance.

The good news is that a balun of this type could be easily devised **Fig. 7**. But the bad news is that the improvements are only marginal, if any, and did not warrant the extra complication of a variable capacitor.

If you can measure the required capacitance, it is always possible to connect a fixed capacitor, 120pF for f=27.185MHz, instead of a variable capacitor. It could have a small trimmer in parallel.

This balun could be useful where you have to tune to more than one frequency and still keep a perfect balance. It could also be useful where you need a splitter to feed two signals, phased 180°, to two unbalanced antenna systems.

What has been said so far does not say anything about efficiency and radiation pattern. No tests were carried out in this regard but a test on the gain gave an average of 6dB for a cb antenna wired as in Fig. 5. The test was done by comparison with a known 3dB gain antenna: about half the power was required from a coaxial antenna to get the same signal reading. ■

References

1) Straw, D R, editor, The ARRL Antenna Book, 17th edition, American Radio Relay League, Inc., Newington, CT, USA, pp. 9-8.
2) Dye, N and Granberg, H, 'Using RF Transistors,' *Electronics World*, August 1994, p. 694.
3) Formato, R, 'Feeding off-centre Dipole,' *Electronics World*, November 1996, p. 853.