Figure 1
X3 40 metre Antenna

EXPERIMENT WITH THE X3 ANTENNA CIRCUIT UNBALANCED

[The article describes how the transmitted field strength can be increased two S points by unbalancing the antenna circuit and allowing current to flow in a longitudinal mode]

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[Updated June 27, 2005]

Forward

The original balanced 40 metre X3 antenna is shown in figure 1. The antenna is driven in its balanced form via open wire tuned line and a Z Match Tuner as shown in figure 2. In this arrangement, the antenna has been given signal reports around 2 S points below the level of a reference end fed half wave inverted V antenna with its apex about 10 metres above the ground. Received levels are also several S points below that from the inverted V. Considering that I now believe there is no enhancement from crossing E and H fields, these figures seem consistent with those which could be predicted from a simple dipole. (For more detail, refer to the previous article.)

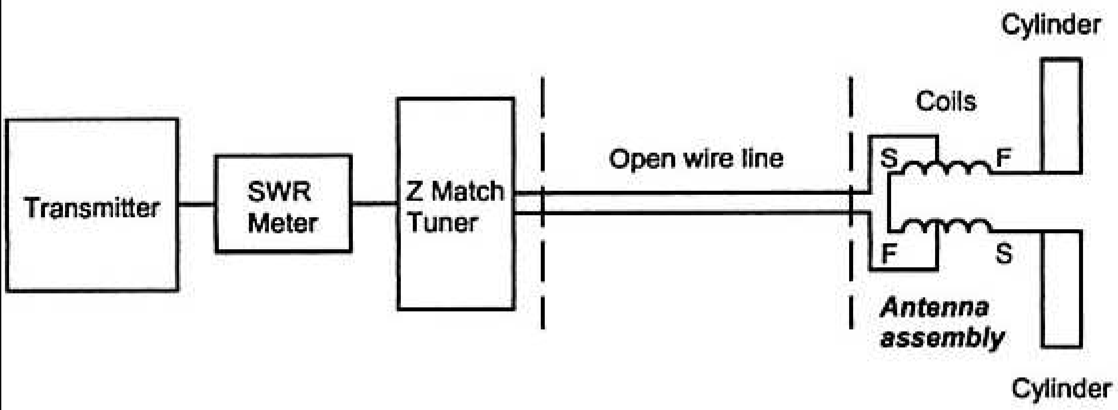

Figure 2 - VK5BR_X3 Antenna Tuning & Matching System

Much of the information gathered for the EH antenna seems to point to best performance when the antenna has a degree of unbalance to generate a longitudinal (or common mode) current in the antenna system. In both the L+T and Star EH antennas, one dipole leg is directly connected to the braid side of the transmission line. For the L+L EH antenna, we found it necessary to wind one inductor with less turns than the other. When the Star antenna was tried in balanced form, it didn't perform so well.

Following along this theme, some tests have been carried out to see what happens when the X3 antenna circuit is deliberately unbalanced making it look more like the type of circuit used in the Star EH antenna which has one dipole element directly connected to one leg of its transmission line. I tried several connections using the coils as they exist with their fixed taps. The connection arrangement shown in figure 3 seemed to produce the best field strength result. I will give reference to this antenna arrangement as the X3U.

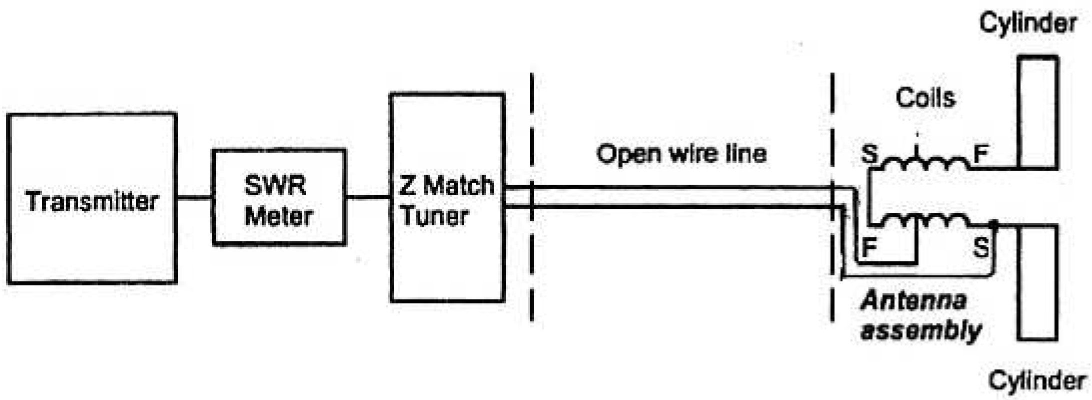

Figure 3 (X3U) - X3 Antenna Tuning & Matching System with antenna circuit unbalanced

Using this X3U arrangement, there was still field measurable around the dipoles but much less than for the balanced connection of figure 2. However using an H field detector with LED display, I was able to track consistent magnetic field right down the length of the transmission line from the antenna to the Z Match output. This was clearly caused by unbalance of current between the two legs of the line.

The X3U antenna was hung about 2 metres above the ground with the feedline on average about 1.5 metres above the ground. There was 7 metres of feeder in open space plus 4 metres entry under the car-port and shielded by its steel roof. On test, the received level now appeared slightly higher than the inverted V antenna. On transmitting, I received several signal reports from stations on the east coast of Australian. These reports indicated similar signal levels being transmitted from either antenna. Further reports on another day from a network of stations put the X3 at a higher level than the inverted V.

From the tests, I conclude that by putting the short balanced dipole out of balance, the field strength is increased from that inherent to the short dipole to something close to that of a full sized half wave antenna.

What I think happens is that the tuned dipole takes over the role of being prime radiator to providing a differential termination for the transmission line. But because of the unbalance, a longitudinal (or common mode) current component also runs on whatever length of line is now left without a balancing or common mode rejecting interface. This current tends to be quite high at the antenna end of the antenna system compared to a base loaded antenna system which has very low current at its apex. One might consider that the dipole, resonated with its inductors, forms a sort of top loading function to the common mode current component.

In the May 2004 issue of Amateur Radio concerning EH antennas, I discussed how the unbalance leads to unequal dipole leg currents via capacitance to earth Voltage at the dipoles is multiplied by the very high Q of the shortened antenna circuit and this leads multiplication of those currents.

I figured that more measurement might reveal how the longitudinal current component might vary over the length of the line. It did seem to me that if the antenna coupling was set such that the dipole circuit loads the transmission line with resistance equal to the line characteristic impedance, current in the line (even if unbalanced) would possibly be fairly constant over its length.

I was able to monitor more carefully the relative strength of common mode current down the line, feeding the X3U, by sliding down its length (over both wire pairs) a large ferrite toroidal core coupled to a milli-ammeter with detector (Refer Figure 8). The tests showed maximum common mode current at around one quarter wavelength down from the antenna and at about 3 times the current near the antenna input and the Z Match Tuner output. The current maximum could be shifted to the antenna entry point by shifting the location of the Z Match tuner so that the open wire line section was 7 metres long and less than 1/4 wave. This current was near constant to a about 4 metres down the cable, and falling to a low value at the output of the tuner. However later air tests indicated lower signal strength than when the open wire line was extended to the Z Match tuner via the extra 4 metres under the car port.

While I was on the job, I took the opportunity to compare these results with common mode current for the balanced X3 antenna. At the maximum current point, the X3 common mode current measured close to 7 dB below that of the X3U and the ratio between maximum and minimum current was about 2 to 1. This all goes to demonstrate that despite little evidence of much field around the transmission line feeding the balanced antenna (as detectable on the LED display detector), it is difficult (if not impossible) to achieve a perfect balance.

With all that under my belt, set about repeating the experiment for the 20 metre and 80 metre X3 antennas using the out off balance connection. Even better for these antennas, the common mode maxima was at the topmost end of the open line where I figured it might be most effective. For the 80 metre test, the common mode current was almost constant over the 13 metre length of line

One objection raised for allowing the feeder line to be part of the antenna system in the EH antenna was the interaction between antenna tuning and the length or position of the feeder. The same applies to the unbalanced X3 but tuning correction is easily made in the radio shack using the Z Match Tuner.

Single Coil X3U

Having decided that the X3 antenna works better not balanced, there is no need for two coils. So I replaced the two coils of the 40 metre antenna with a single coil wound around the existing insulated supporting plates which hold together the dipole plates. (See Figure 4 and 5).

The coil consists of 24.5 turns wound on the 12 cm x 6 cm square former provided by the plates and tapped at 7 turns. The dipole legs are the original 50 mm square galvanised iron pipes each 50 cm long. It is very simple to set up with nothing critical to adjust. Simply wind enough turns of the coil until a coupled dip meter indicates that the coil parallel resonates with the dipole capacitance at a frequency around the centre of the band. Precise tuning is trimmed using the Z Match within the radio shack.

As I expected, the single coil unit worked equally as well as the unit fitted with the two coils and it gave on air results comparable with those of my reference full size inverted V antenna.

Figure 4 The 40 metre X3U antenna using a Single Coil

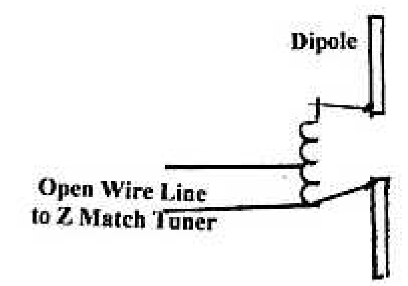

Figure 5

Some Conclusions

From my more recent investigation of why X2/X3 antenna circuit series resistance measures quite high, I have concluded that as far as the balanced form of the antenna is concerned, the high value of resistance is not radiation resistance. I have assumed that radiation is simply that which can be predicted as normal in any dipole and not due to crossed fields as originally assumed.

However, by unbalancing the form of the dipole (as for the X3U connection) so the feedline is activated with common mode (or out of balance) current, the radiation level can be raised to nearer that of a full sized resonant dipole.

In the form of the X3U, the circuit of the antenna looks very much like that of the Star EH antenna. A difference is that loading coils of the X3U are placed at the centre of the dipoles where their magnetic fields had been aimed at crossing the dipole electric field. Also whilst the Star antenna has a series phase correction coil, the X3 antenna has the equivalent by reflected reactance via the open line from the Z Match tuner.

So it seems that first setting out to make a balanced small dipole which was supposed to demonstrate how interacting or crossing its electric and magnetic fields could enhance its radiation, we have discovered that it doesn't. But instead if we put the antenna circuit off balance, we have a magnificent top loading device for a radiator formed from the feedline out of balance current.

Furthermore by making use of that characteristic, we can simplify the construction to just one central coil which can mounted in any orientation because we are no longer concerned with the direction of its field. This makes a compact antenna system, very simple to assemble and set up and which works extremely well.

From what we have learned about the EH antenna, it's antenna circuit is clearly unbalanced and it does seem to need at least a short feeder tail for best operation. I suspect that the same sort of explanation, as I have discussed here, can also apply to the EH antenna.

Balanced Trap for Open Wire Line

Figure 8
Measuring of Common Mode
Current on open wire line to the X3 Antenna

Having established that the X3 antenna can work better in an unbalanced mode with longitudinal current flowing in the feeder, the question arises whether a common mode current trap might be useful in the feeder line as was applied to the coax line of the EH antenna. As far as the EH antenna is concerned, there are several functions which the trap can perform:

(1) Elimination of longitudinal or common mode current getting back into the radio shack to cause such problems as RF feedback. .

(2) Blocking of current loop which returns via earth - a possible waste of power in earth loss.

(3) Selective placement of the trap to control the where the common mode current maximum can be used to best advantage.

In the case of the open wire line operated with X3 antenna in an out of balance mode, the common mode current is brought back right into the radio shack to the output coil of the Z Match tuner. So there is some RF entering the shack. We also then rely on the ability of the Z Match output circuit to block the longitudinal component. This is not perfect, particularly on the higher HF bands (Refer to my article on "Output Balance of the Z Match").

It seemed to me that it would be useful to make a balanced line trap to fit in series with the open wire line. This would block the longitudinal component where we would like it to be blocked to the best advantage.

The EH antenna traps were wound with coax cable but for the line pair feeding the X3 antenna a paired cable was required. So I made up the trap for the 20 metre band using "figure of 8" power flex as shown in figures 6 and 7. Initial tests indicate that the trap is working well to inhibit common mode current component just as the coax traps have done. Common mode current is monitored using the device shown in figure 8. On the transmitter side of the trap, common mode current is almost dead.

Note that in winding the flat twin as I have done, every turn is adjacent to the next turn of the opposite line leg. I thought perhaps excessive capacitance between these might not be desirable and that is why I have spaced each turn pair apart from the next.

The balanced trap can be a useful addition to the tunable line fed to the X3 antenna operated in the unbalanced mode. This particularly applies when the line is greater than a 1/4 wavelength long and in this case, the trap is placed in the line around 1/4 wavelength from the antenna. So far I have only made and tested a balancing trap for the 20 metre band.

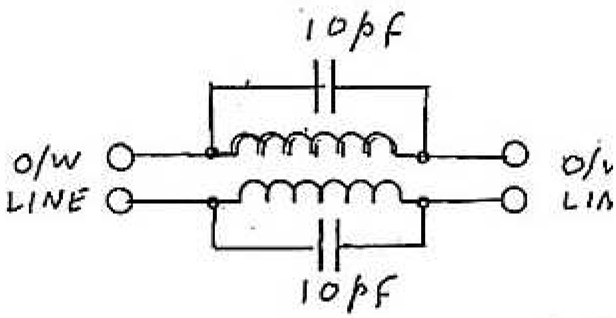

Figure 7
Balanced Trap for 20 Metres

Figure 6 - Balanced Trap for 20 Metres

13 turns of "Figure of 8" Power Flex, space to 11 cm.
Former - 4 cm diameter
Inductance 6.5 uH
Parallel Resonant at 14 MHz
(Tuned with 2 x 10 pF capacitors)

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