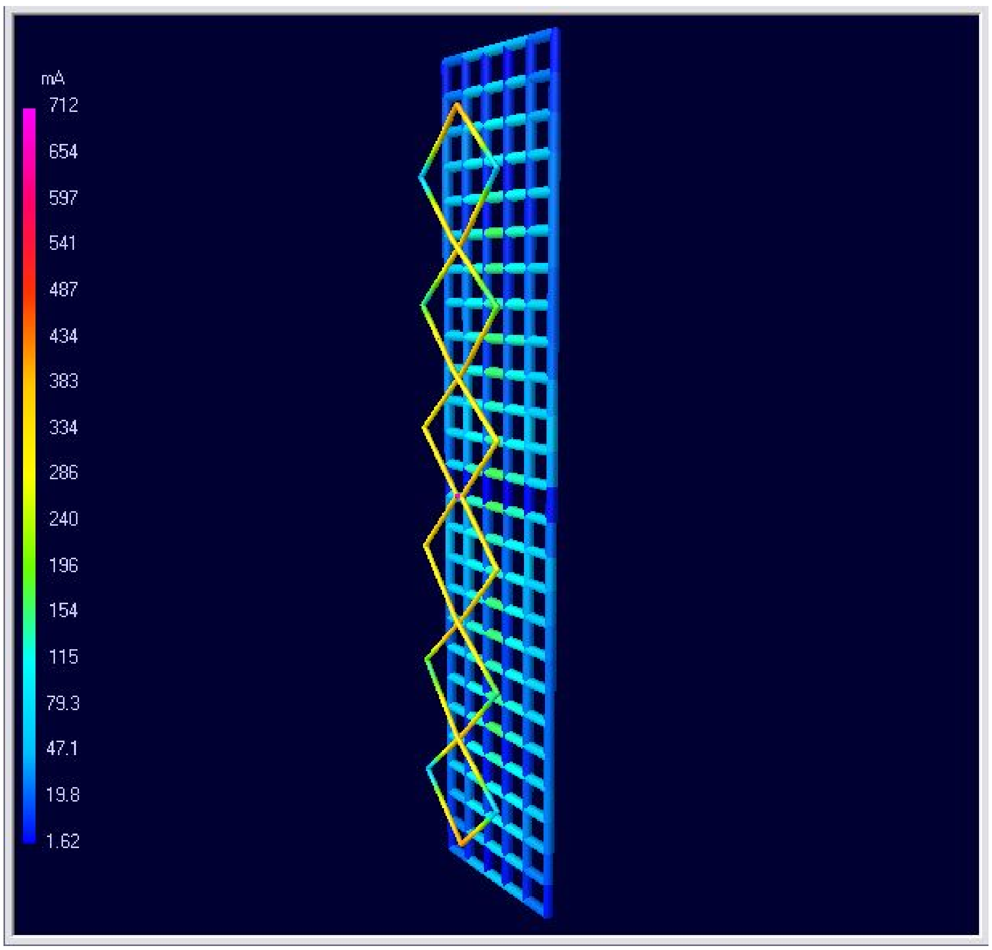
Quados Sector Antenna for 2.4 GHz WiFi

Dragoslav Dobričić, YU1AW

Introduction

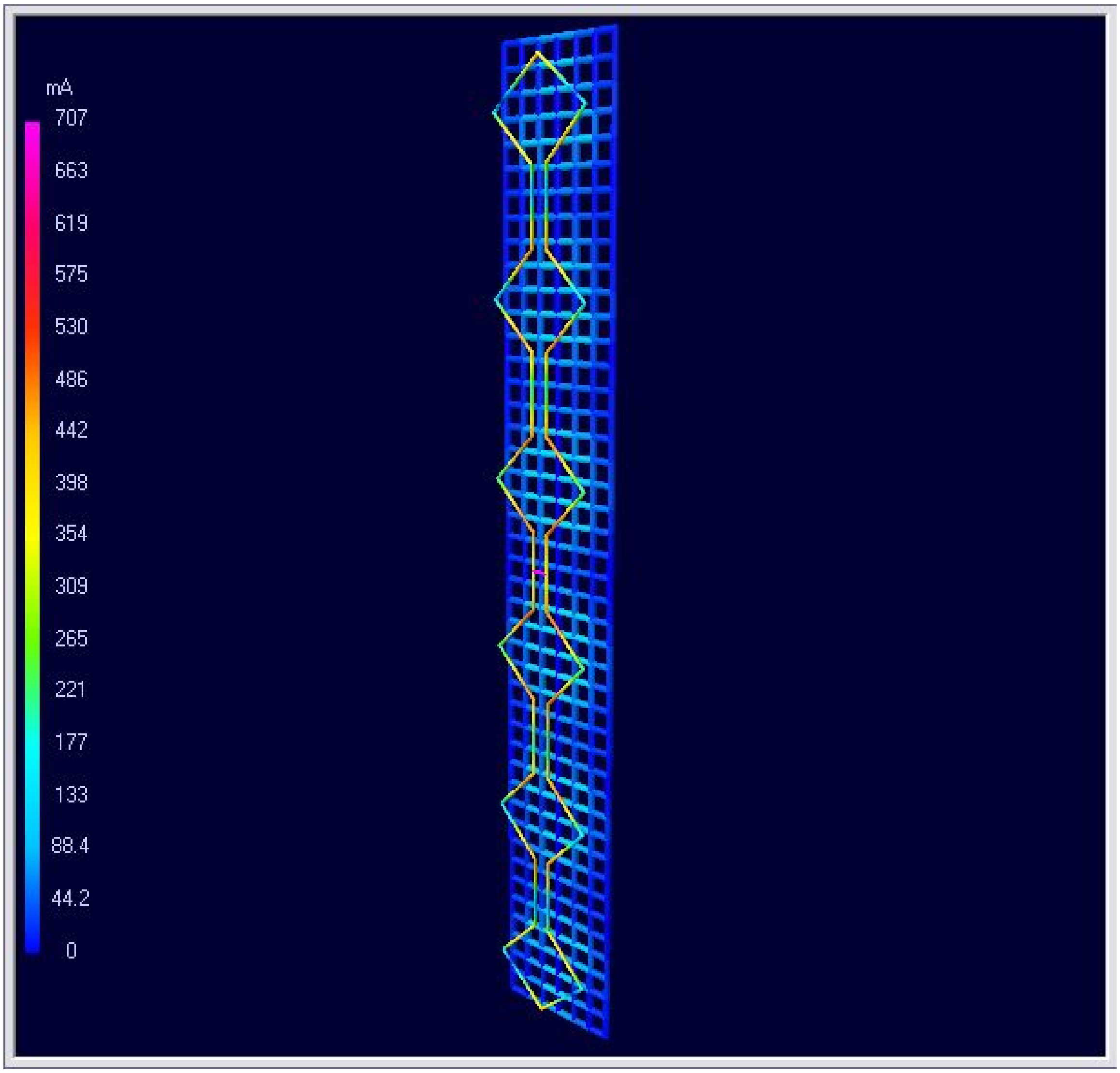
After successful construction of the Amos **[1]** and Inverted Amos **[2]** sector antennas, which are vertically polarized when they are used as sector antennas with wide horizontal and narrow vertical diagrams, I decided to try to construct an antenna with similar performance, but with horizontal polarization. The bi-quad antenna was very interesting as a starting point design and I tried to add more quad elements to get higher gain and narrower vertical diagrams. After some time of computer optimization I found that bi-quad antennas with two more quads added gave a very small increase in gain compared to the original bi-quad antenna, and the expected 3 dB difference is impossible to achieve. Another two quads were added and after optimization, the results showed an even smaller increase in antenna gain than expected. I was convinced that some problem existed and that simply adding quads does not give the expected increase in gain of roughly 3dB with every doubling of element numbers. I expected that the increase in gain will not follow 3dB for system doubling due to lower currents in far quad elements but overall gain was even lower then that expectation.



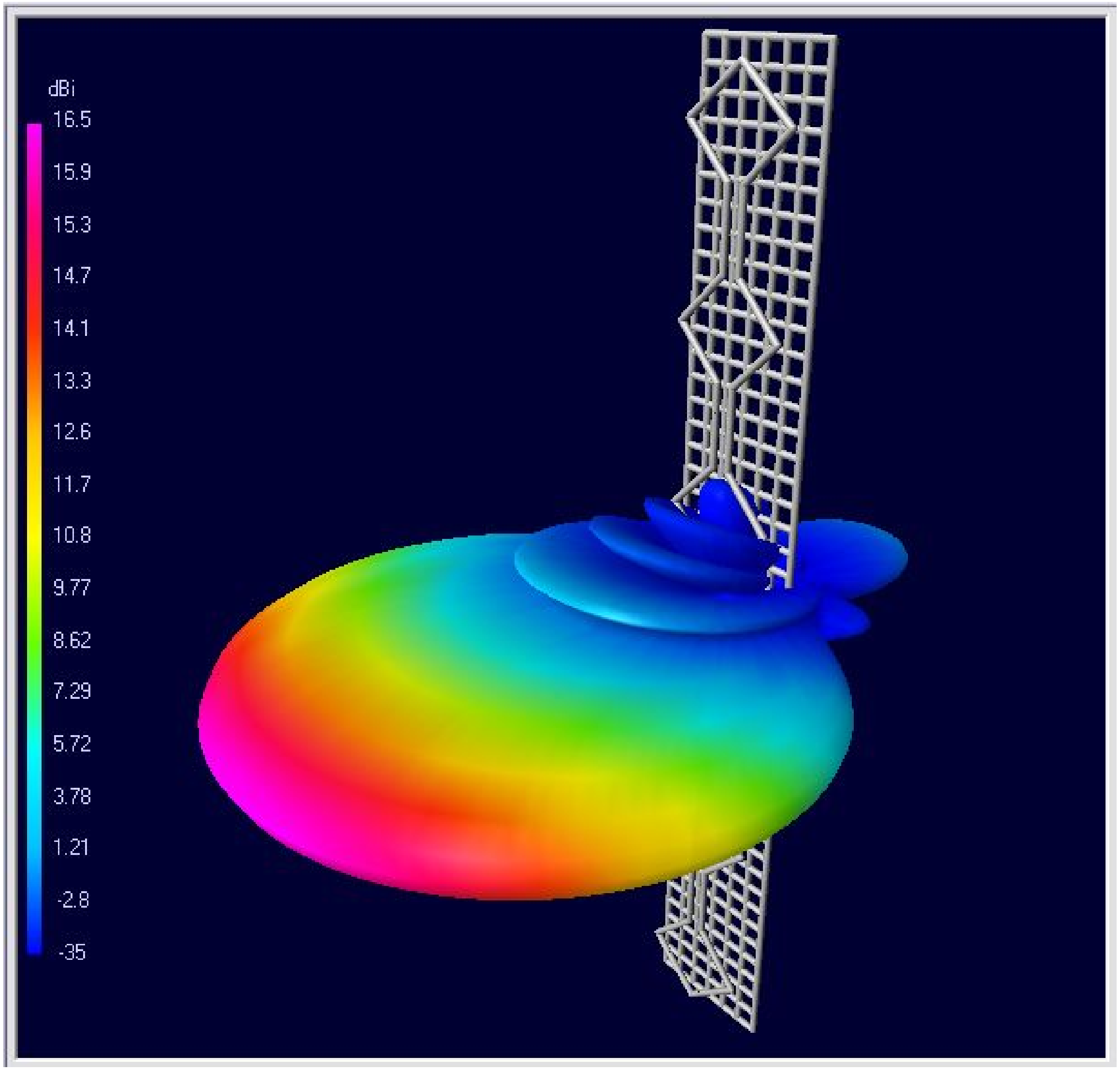
Currents in elements of six-quad antenna

The solution to the problem with gain

After some brief analyzing I concluded that problem is in very close stacking distances between quads. Close spacing between quads gives under-stacked quads an overlap to their effective apertures and thus they didn't produce 3 dB gain increase for every doubling of quad element numbers.



Currents in elements of Quados antenna with 6 quad elements

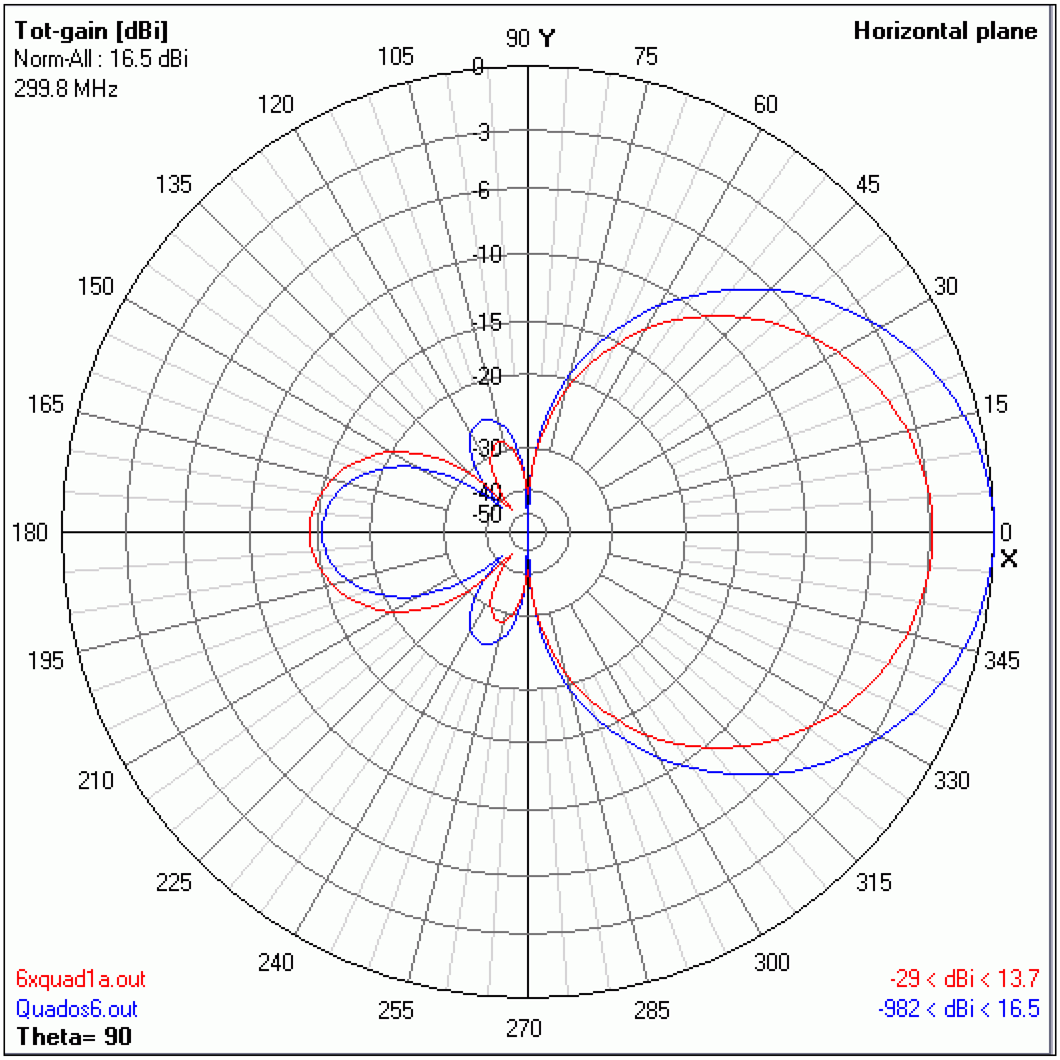


3D radiation diagram of Quados-6 antenna with 6 quad elements

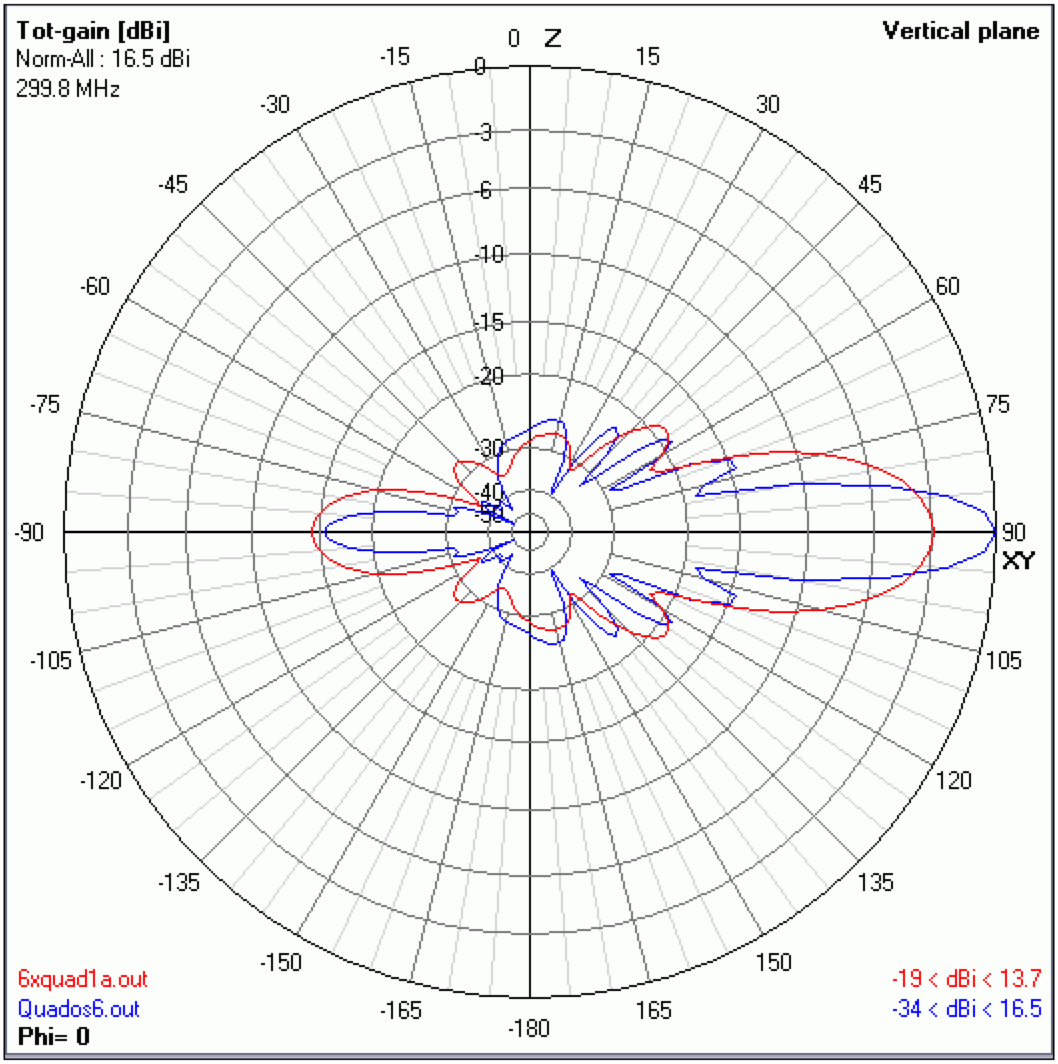
The solution to the problem with feeding

It became obvious that it was necessary to increase stacking distance between quad elements. This raises new problem – how to feed stacked quads, because very simple feeding of the original bi-quad antenna obviously became impossible. I decided to feed them with open two-wire transmission line. At such high frequencies, open wire line can work but they must not have too high an impedance value due to very large distance between wires, which become a considerable part of wavelength. On the other hand, too low an impedance value and too close spacing becomes impractical for NEC optimization because of NEC limitations of how close two parallel wires may be for accurate results of simulation.

With careful segmentation and wire diameter choice I did my best and relatively successfully solved problem of satisfactory accurate open wire simulation. I found best compromise between imbalance due to large wire spacing and NEC error due to close wire spacing. Results are not perfectly accurate but show that they are accurate enough for this purpose.



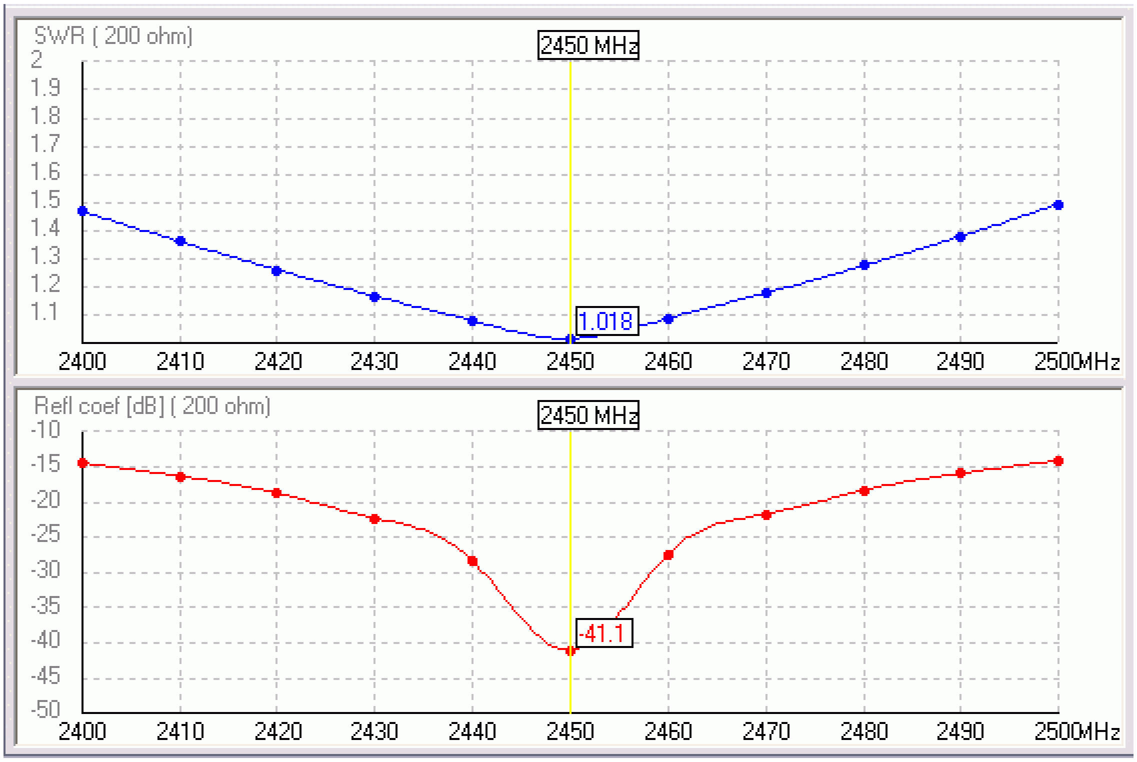
Horizontal radiation diagram of Quados-6 and six-quad antenna



Vertical radiation diagram of Quados-6 and six-quad antenna

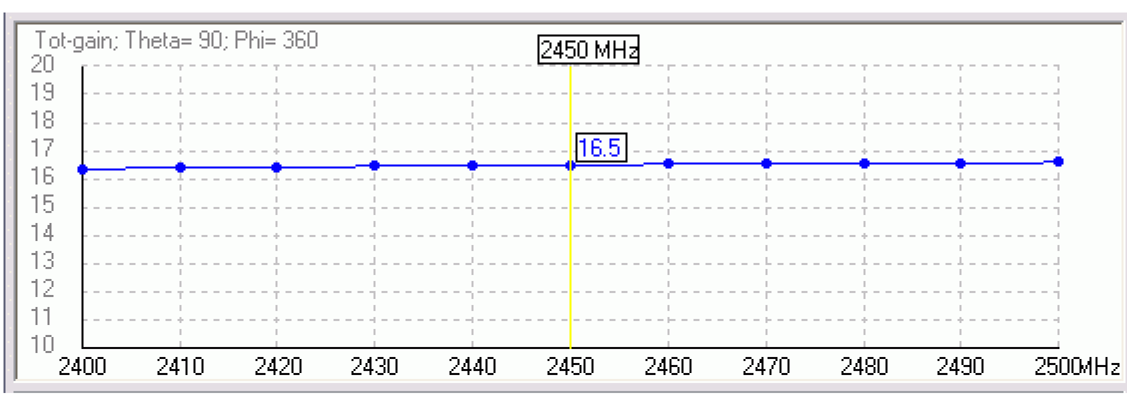
Achieved calculated results

Optimized new Quados antennas with 6 quad elements give almost 3 dB more gain than multi-quad antenna with the same number of quad elements. As it can be seen from compared diagrams, Quados has even little wider horizontal diagram and a considerably narrower vertical diagram. That was my target when I started the construction of the horizontally polarized wide-angle sector antenna.

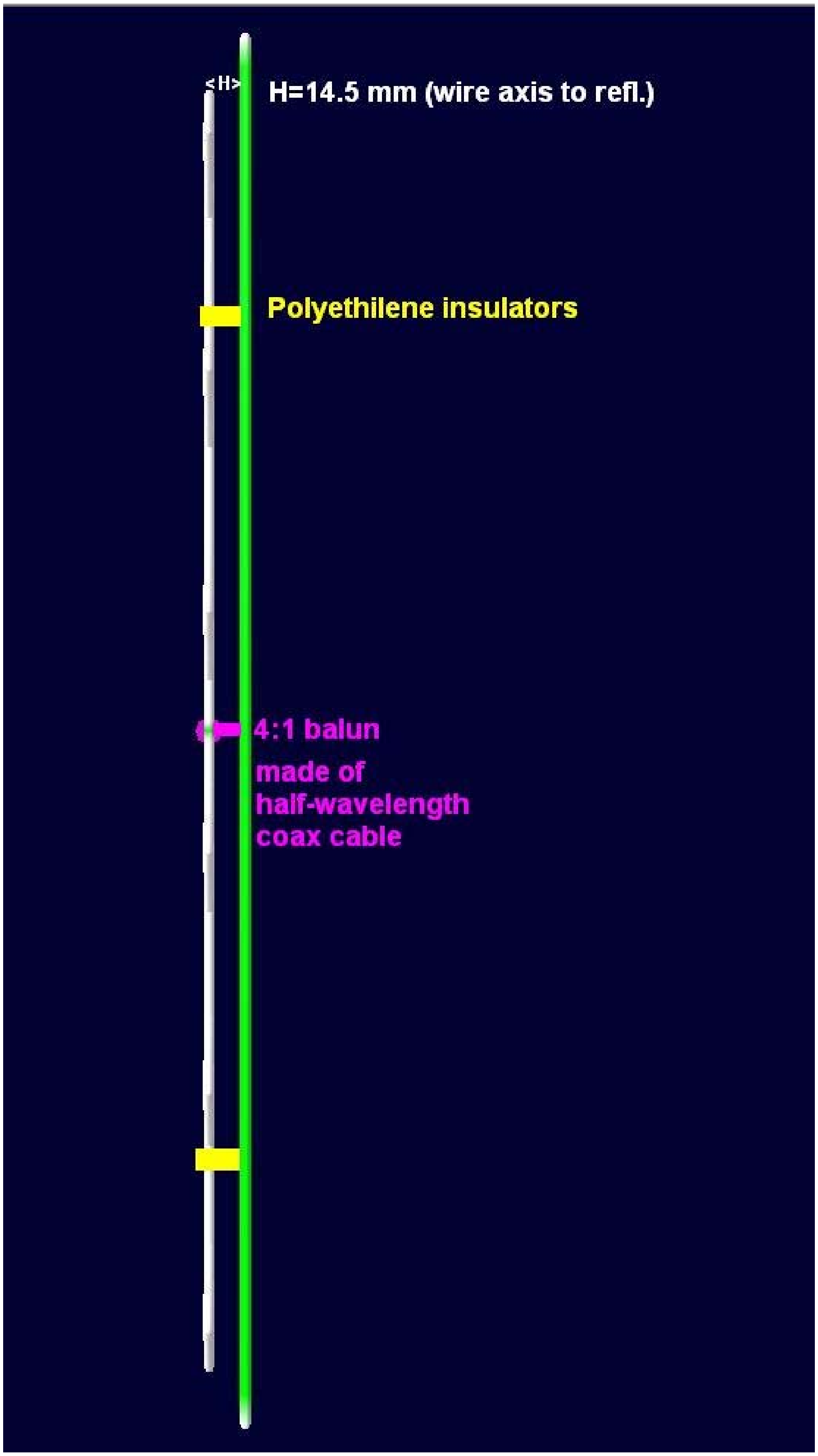


SWR and Return loss diagram of Quados-6 antenna

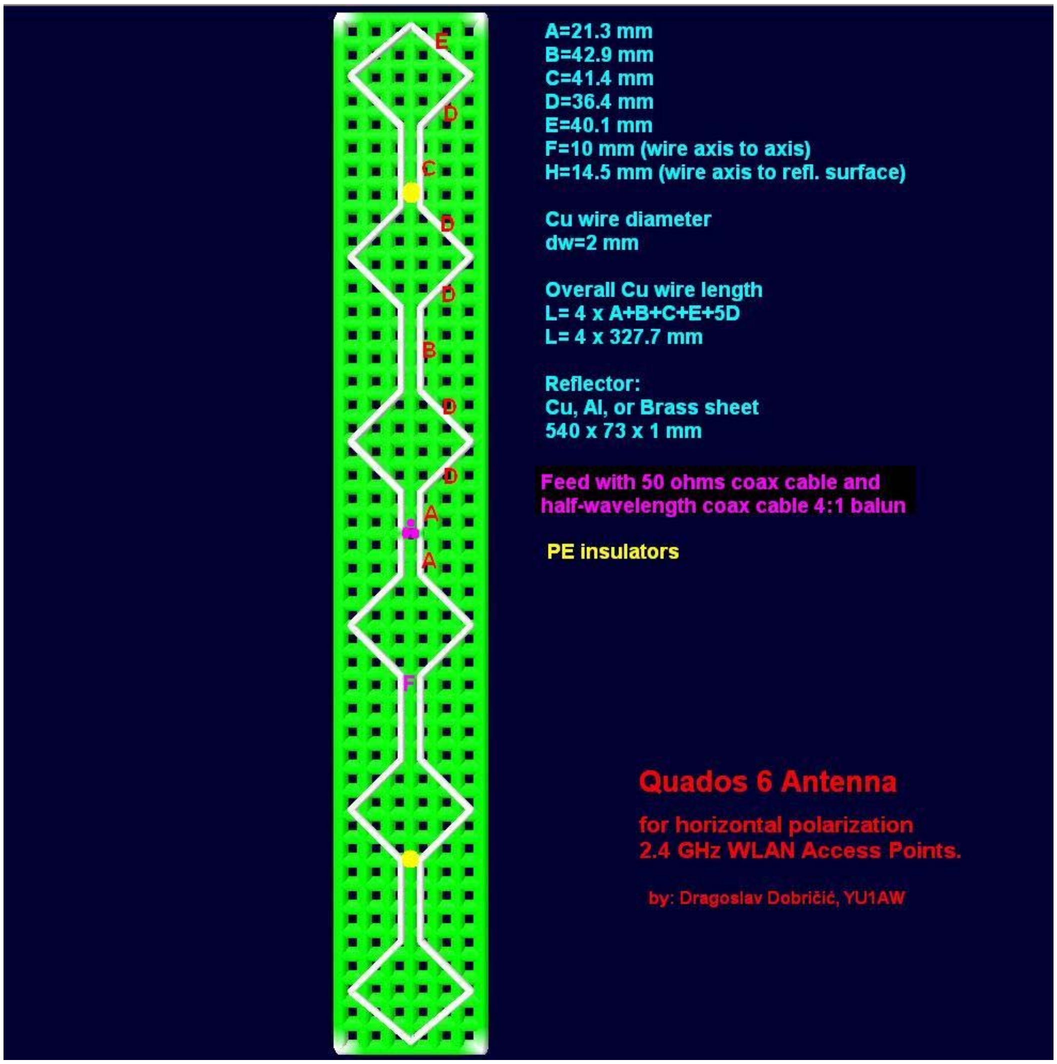
This way I achieved an antenna with a relatively wide radiation diagram in horizontal plane, about 65 degrees for -3dB and about 90 degrees for -6dB decrease of the gain. With very accurate symmetry of the antenna geometry and the currents within, I achieved a clean diagram in the vertical plane, with the width of the main beam of 10 degrees for – 3dB and with very good side lobes suppression. The relatively high radiation resistance of the antenna gave a low antenna Q factor and high width for the frequency working band that can be seen from the antenna input matching diagram. The gain of the antenna of over 16 dBi is very close to the theoretic maximum for this kind of configuration and is completely acceptable for the antenna with this wide radiation diagram in horizontal plane. This is achieved by careful optimization on the computer, using **4NEC2,** a NEC based antenna modeler and optimizer by Arie Voors.



Quados-6 antenna gain diagram.



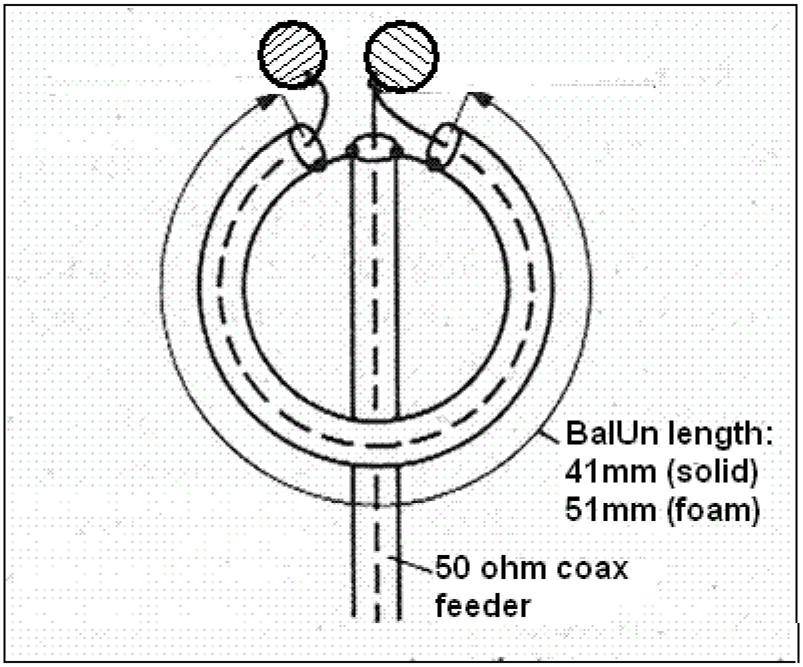
Distance of Quados-6 antenna quad elements from reflector surface



Dimensions of Quados-6 antenna

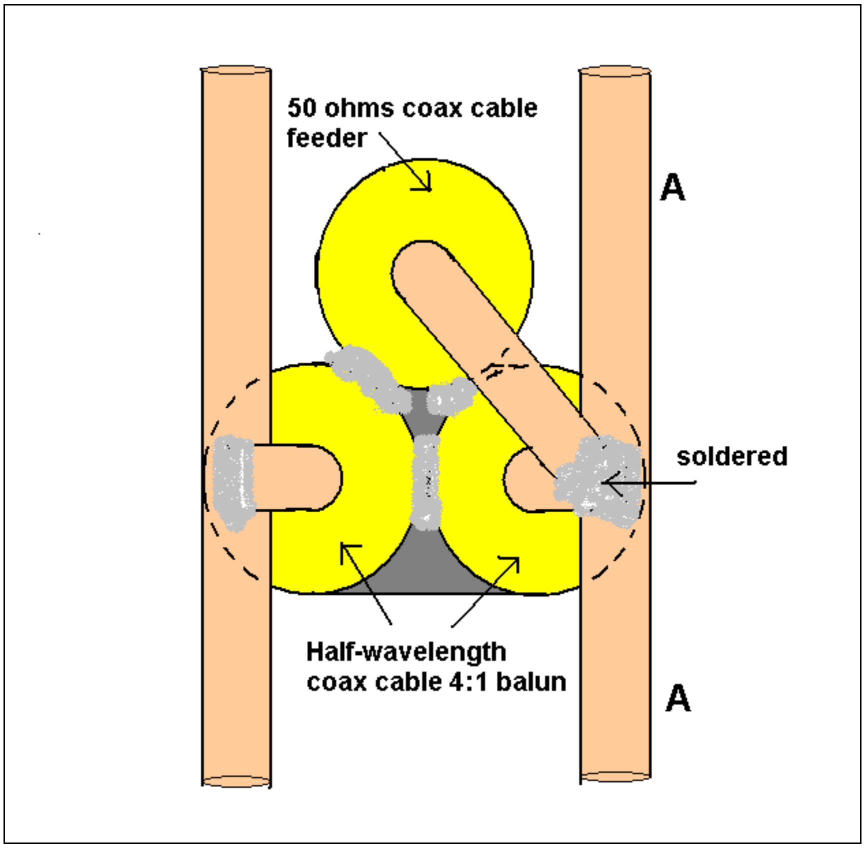
The half wave BalUn construction

Feeding and the 1:4 half wavelength coax cable BalUn construction is same as for Amos antenna **[1]** because of the same input impedance of antenna of about 200 ohms. The half wavelength BalUn is made of a piece of the coaxial cable whose length depends on the type of the cable! If the cable with full solid dielectric is used, like RG58A type cables, then the velocity factor for that type of cable is v=0.66 and the length of the BalUn is 40.7 mm. But, if cable with foam isolation is used, like CFD200, then the length of the BalUn should be 51 mm, because the velocity factor for that type of cable is v=0.83. The BalUn cable length is the length of the outer conductor before folding, while the length of the inner conductor must not exceed 1-2 mm.



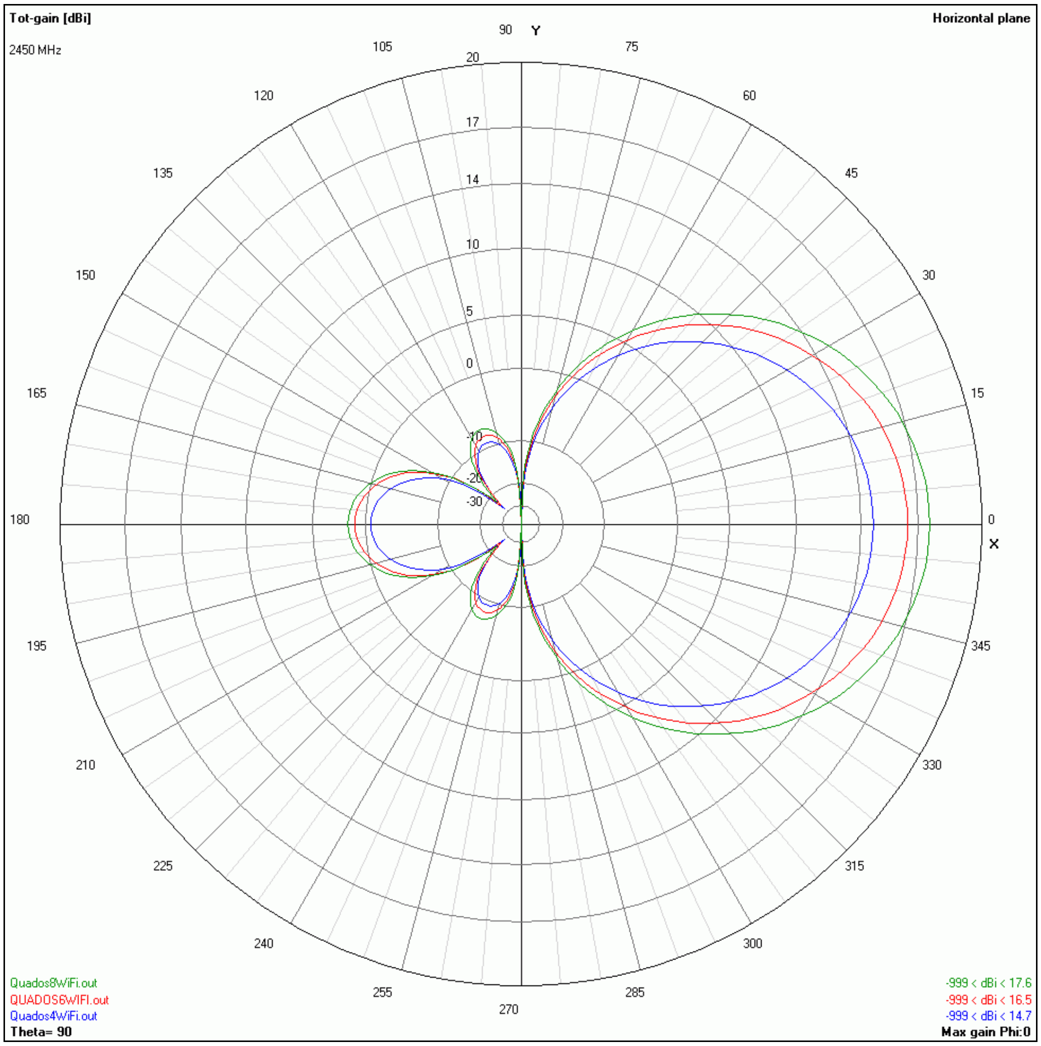
Half wave BalUn connection and its physical length depending on coaxial cable dielectric type

Everything should be soldered as short as possible in order to avoid parasitic inductances of the connecting wires. The cables endings are placed in the triangle or line form depending on cable thickens, so that two ends of the half wave BalUn are connected to the two wires of open line as short as possible, and the feeding line placed in the middle is connected with either sides of the open line. The outer conductors of the both ends of the half wave BalUn and of the feeding line are connected directly to each other and nowhere else! It is very important that these connections are as short as possible!

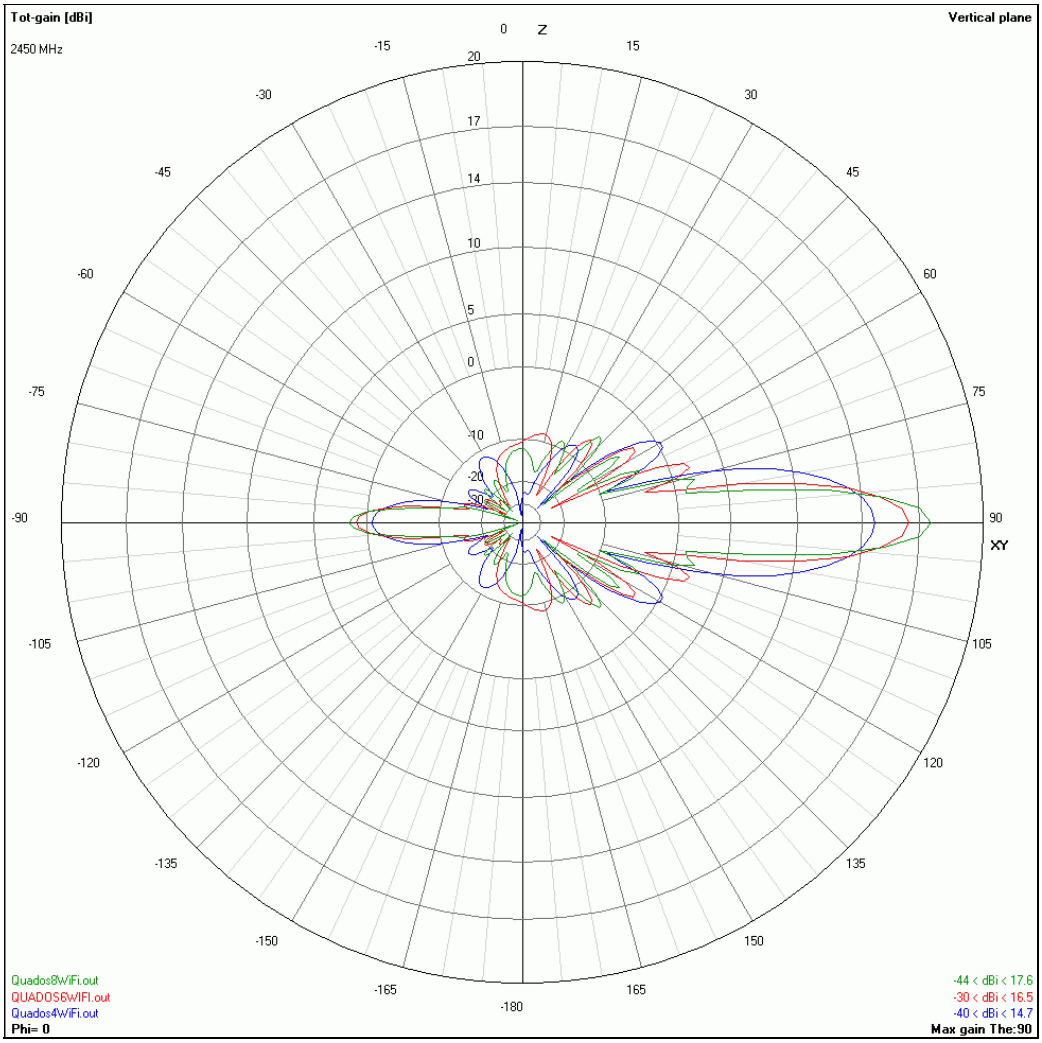


Half wave BalUn connection to two-wire open feeding line

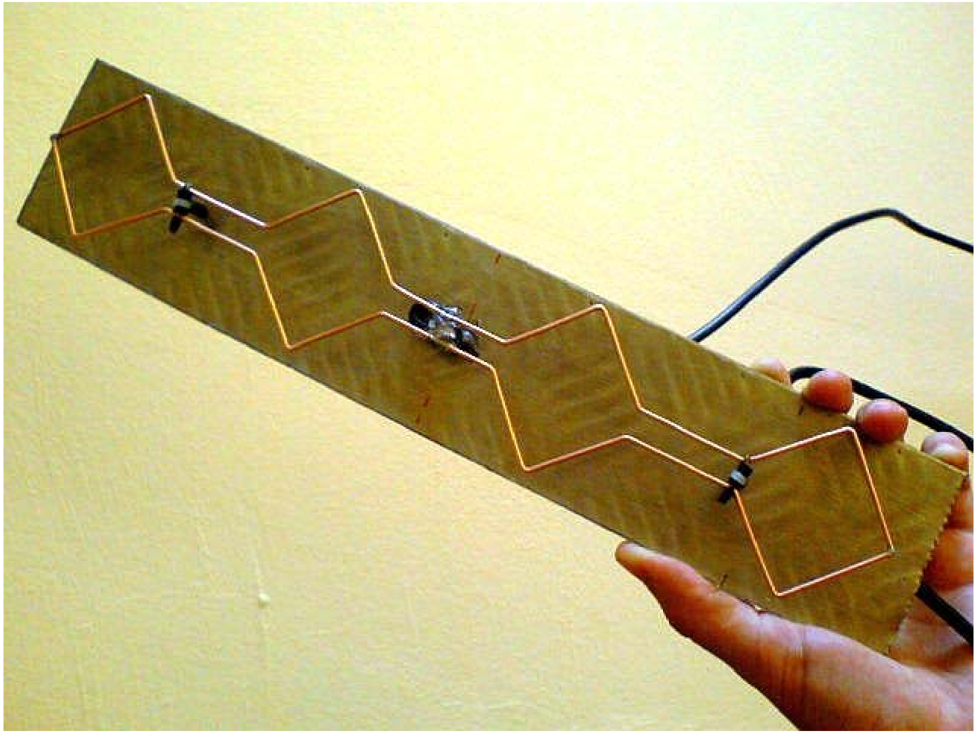
Preparation and soldering of half wave BalUn and feeding coaxial cable



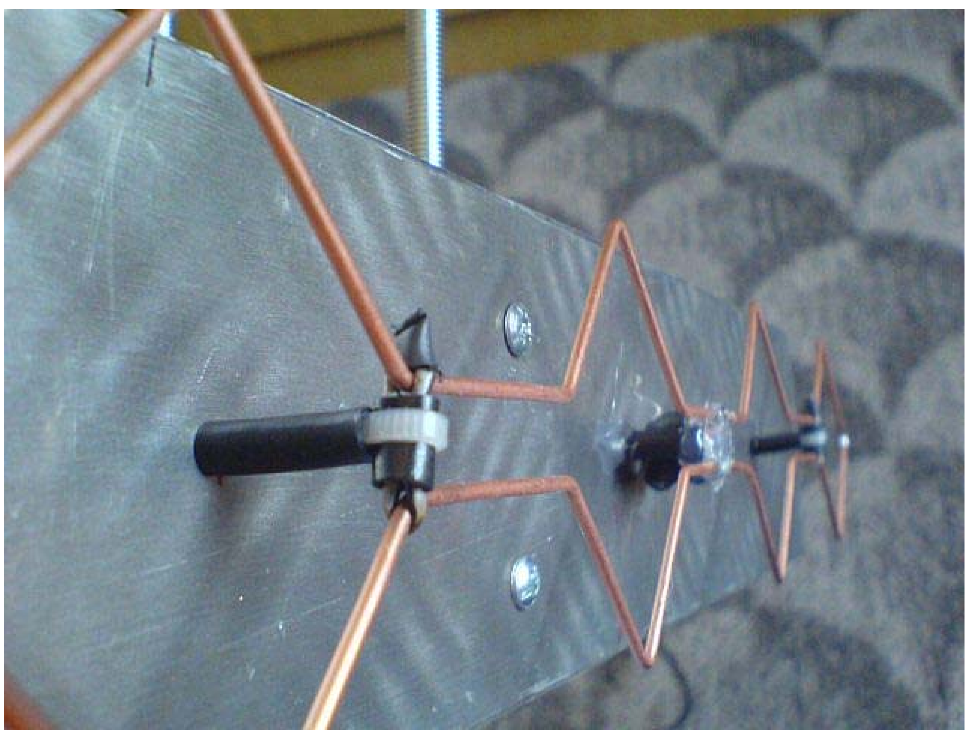
Horizontal radiation diagram of Quados antenna with different number of 4, 6 and 8 quad elements



Vertical radiation diagram of Quados antenna with 4, 6 and 8 quad elements

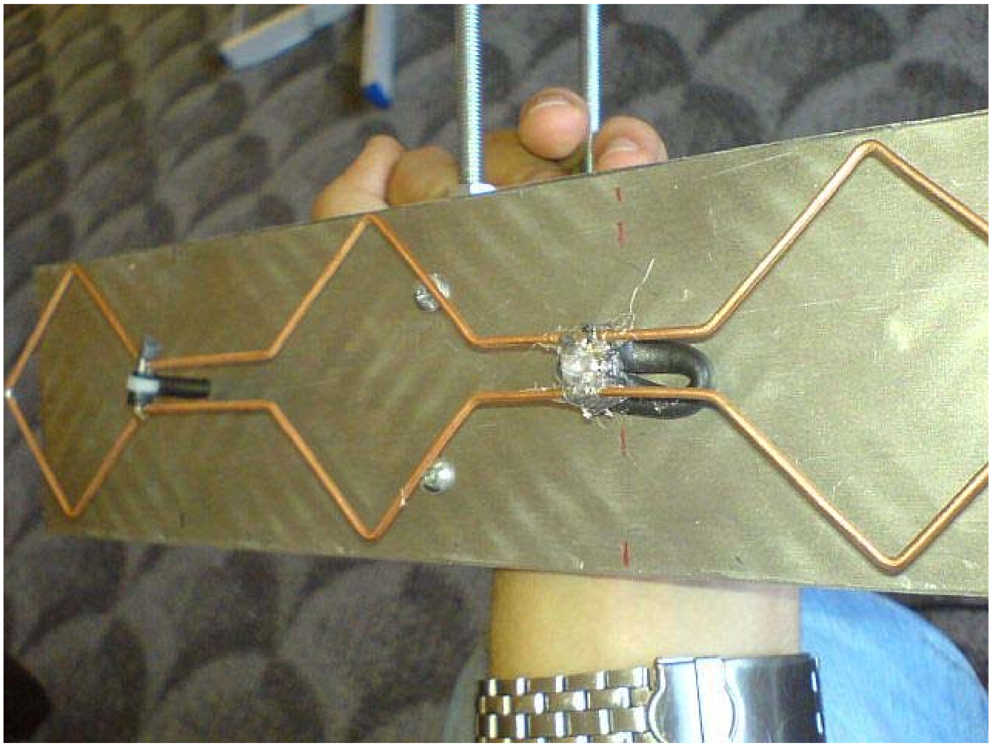


Finished Quados antenna with 4 quad elements

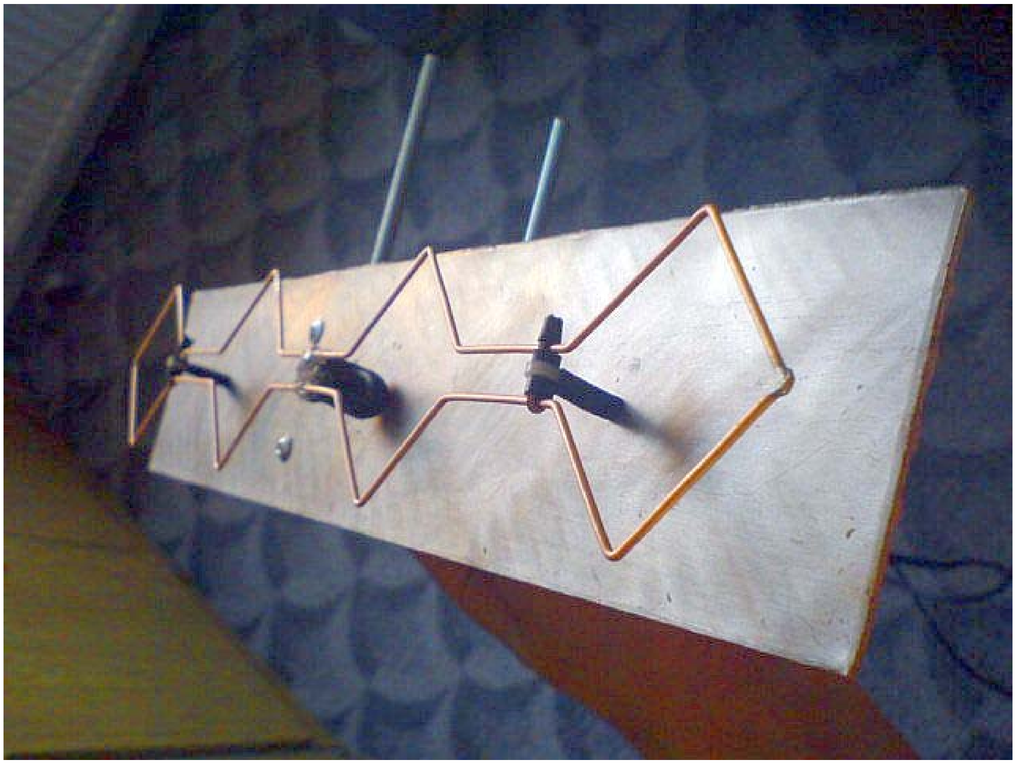


Polyethylene water protection of cables and soldered junctions

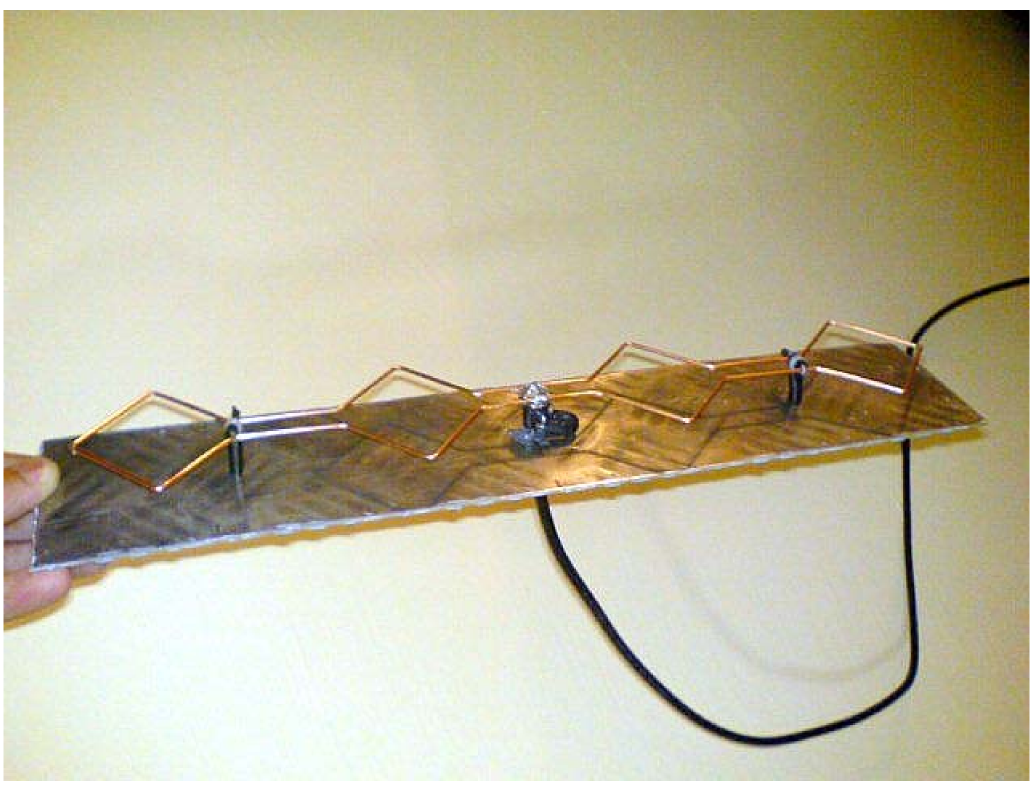
Feeding coaxial cable and BalUn position
with polyethylene water protection of cables and soldered junctions



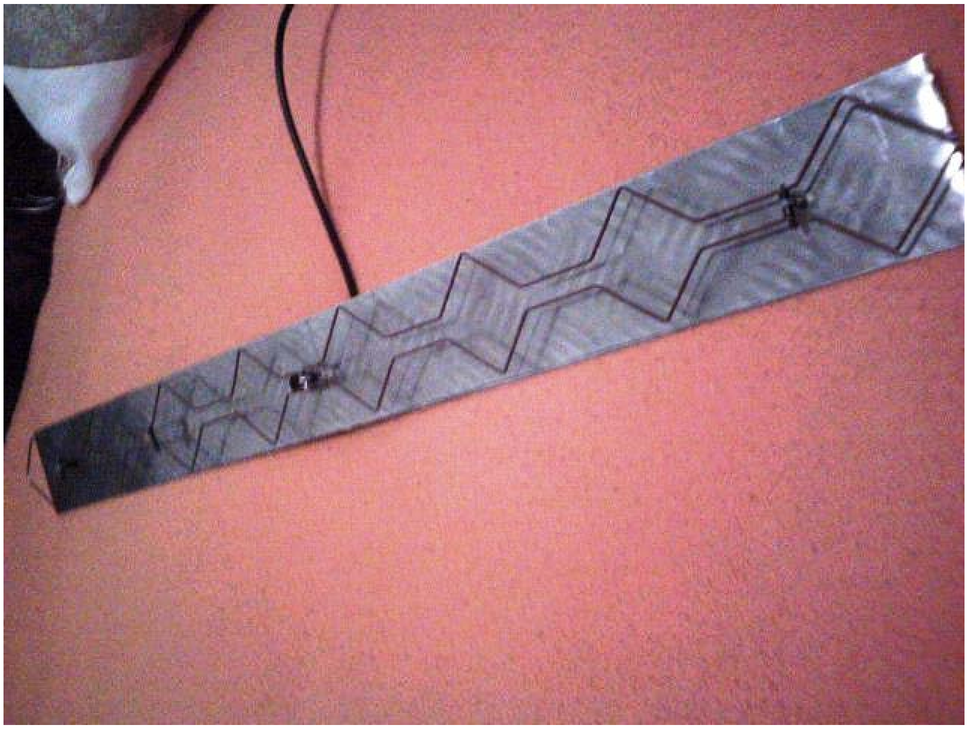
BalUn and feeder soldered to two-wire open line



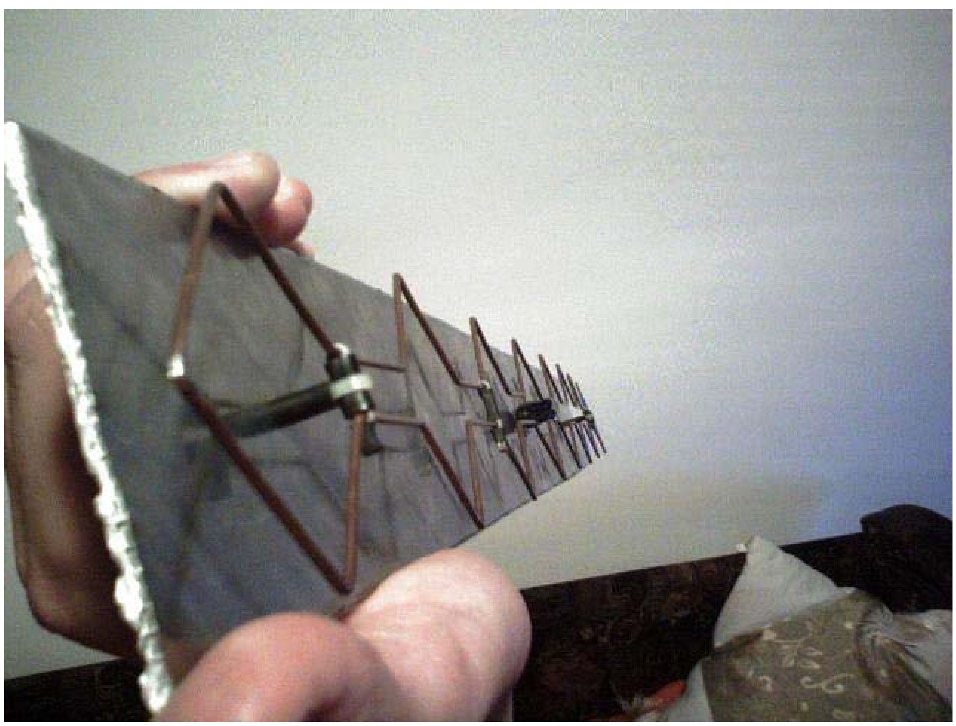
Finished Quados antenna with 4 quad elements



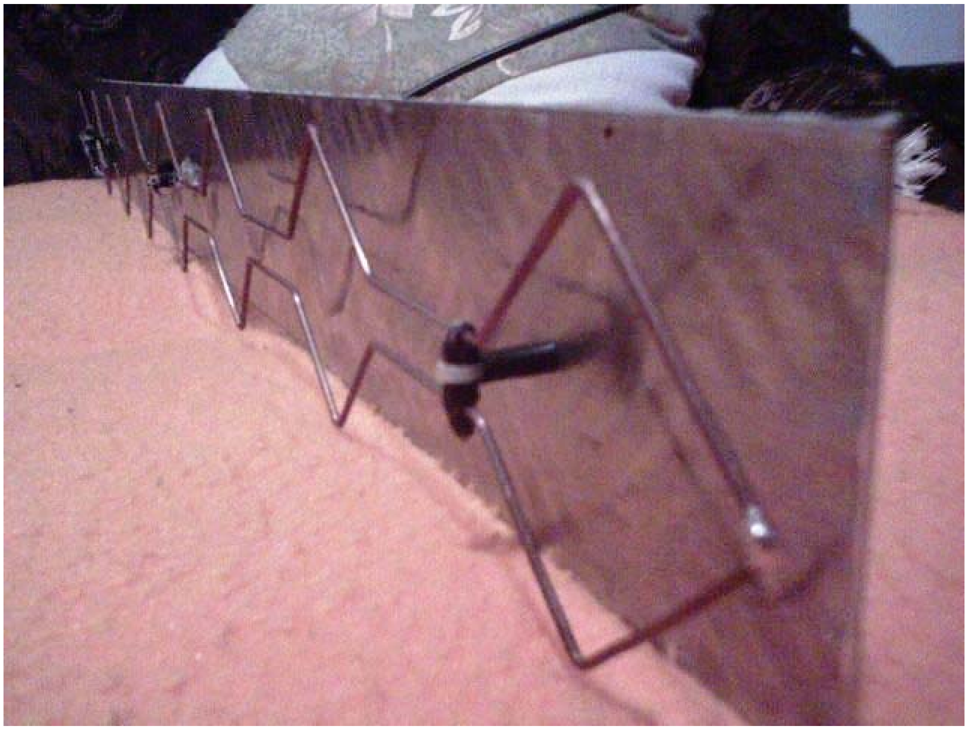
Finished Quados-4 antenna



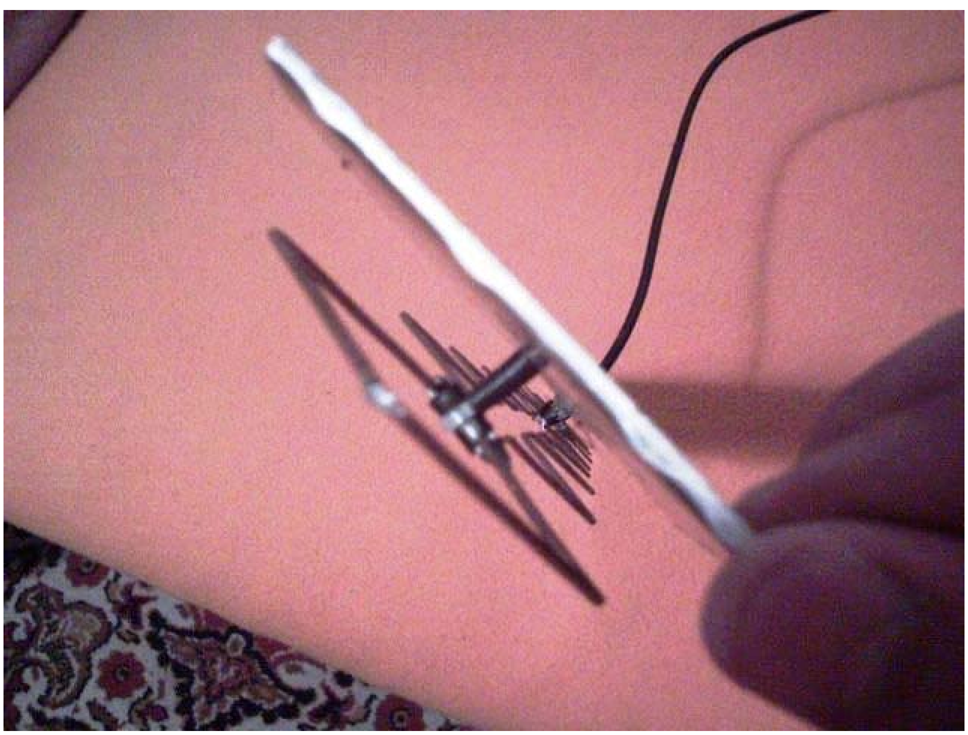
Finished Quados-8 antenna



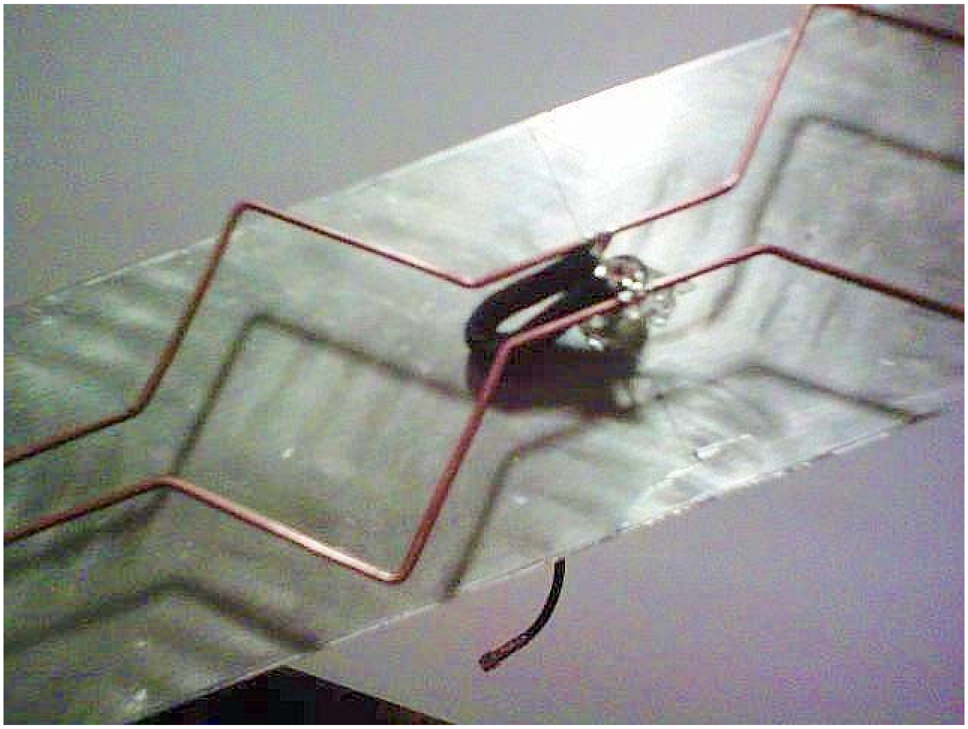
Another view to finished Quados-8 antenna



Another view to finished Quados-8 antenna



Side view to finished Quados-8 antenna



BalUn and feeder soldered to two-wire open line of Quados 8 antenna

Mechanical construction of the antenna

The antenna consists of four copper wires 2 - 2.3 mm in diameter and overall length of 327.7 mm. Each piece of wire is folded in the same way as shown in pictures. Before folding, measure and cut 327.7 mm long wire, then measure and mark spots where the wire will be folded. Polyethylene piles should be made and placed on the wire before folding; these piles will serve as isolators and carriers of radiation elements of the antenna.

Isolating piles

Piles are made of the isolator of thicker coaxial cable (RG-8, RG213) by removing the inner and outer conductors. The length (height) of the piles is about 18-20 mm, and at exactly 14.5 mm from one end the 2-2.5 mm, a hole should be drilled across the pile through which the wire will pass. The piles are fixed by bolts, which are placed on the outer side of the reflector, through the reflector surface and into the existing hole in the pile from which the inner conductors have been removed. The distance between the wire passing through the pile measuring from the axis of the wire to the reflector surface must be exactly 14.5 mm! The dimension from the surface of the wire to the reflector surface is 13.5 mm that is reduced by the radius of the wire! The reflector surface is made of the brass, copper or aluminum sheet metal, 0.5-1.5 mm thick. It may also be made of the single side coppered epoxy, standard thickness 1.6 mm, usually used for PCB making.

The protection from the atmospheric actions

While the copper is still light and corrosion-free, the antenna should be sprayed with a thin layer of the transparent varnish. Before this, the very spot of the soldering of the cables and opened cable cross-sections should be covered with thin layer of polyethylene using the pistol gadget that melts polyethylene rods and deposits liquid plastic on the desired surface. The layer should be waterproof, but as thin as possible! So, it is wrong to put large amounts of the plastic mass in the thick layer on the junction, because it is useless and it can spoil the matching of the antenna! Also, the use of silicone is forbidden because of its chemical aggressiveness and large losses at high frequencies!

The results of the practical work test

The Quados antenna was compared in practice with earlier built 3D corner reflector antenna of about 17.9dBi which I use for WiFi and the acquired results very well corresponded to the expected ones. The Quados antenna received signals from AP with about 1.5 dB lower level than the 3D corner reflector antenna, which was expected with regard to their gain. But, the number of received signals was several times higher because of the wide horizontal diagram! Because of this quality, Quados antenna is designed as an antenna for Access Points and horizontal polarization! It can also be used for clients when it is necessary to, without moving the antenna, to acquire communication with several APs which are located in various directions.

Mechanical fixation to the carrier

This fixation can be performed in any suitable way so that the antenna can be moved horizontally and vertically in order to precisely aim the antenna in the desired direction. The carrier can be made so that it additionally strengthens the reflector surface from the backside if the reflector surface is made of the thinner metal sheet or epoxy without the necessary stiffness for that length. Any metal (especially ferromagnetic) or plastic pieces are forbidden at the front of antenna, near the quad elements or the feeding lines, because they can increase the losses, change the antenna's radiation diagram and input impedance, and consequently the proper function of the antenna itself. All the fixations and mechanical constructions must be placed on the backside of the reflector surface. If thicker coaxial cable feeding line is wanted, female N connector can be put on the backside of the reflector, and through the hole on the reflector thin cable can be connected to the BalUn and feeding line. It is not advisable to connect thick cable directly to the BalUn and feeding line, because it is hard to solder it shortly because it is physically bulky, and antenna impedance can be changed due to parasitic reactance.

Aiming the antenna

During the aiming of the antenna, one should keep in mind that the antenna has very wide horizontal diagram, and the sharp maximum should not be expected while changing the horizontal angle! On the other hand, the vertical radiation angle is very narrow and the maximum of the receiving signal is very sharp, so the antenna should be positioned very carefully and precisely! The antenna is mainly provided for to work with horizontal polarization because of the specific radiation diagram it has while using in that way. The antenna is especially adequate for Access Points due to its great coverage width in horizontal plain.

Conclusion

In this work I demonstrated and confirmed by measuring the possibility of using full wave quad loops in front of the relatively narrow reflector surface and fed in series by open two-wire line as an efficient antenna on 2.4 GHz. The antenna has a horizontal polarization and wide radiation diagram in horizontal plane. The parasitic radiation of feeding two wire lines is minimized by the fact that the current minimum is at the half-length (at the center) of line and in that way, the intensity of its radiation is considerably reduced. In this way the impact of parasitic radiation on the overall radiation diagram is reduced. In addition, placing the reflector surface modified the input impedance to the value that is suitable for efficient matching of the antenna to the coaxial feeding line. Therefore, geometric and electric symmetry of the antenna enabled clean, symmetrical and narrow vertical diagram. By using a very narrow reflector, the great width of horizontal diagram is preserved. **-30-**

References

1. Amos Antenna, *antenneX* Issue No. 127 – November 2007.
2. Inverted Amos Antenna, *antenneX* Issue No. 130 – February 2008.

BRIEF BIOGRAPHY OF THE AUTHOR

Dragoslav Dobričić, YU1AW, is a retired electronic engineer and worked for 40 years in Radio Television Belgrade on installing, maintaining and servicing radio and television transmitters, microwave links, TV and FM repeaters and antennas. At the end of his career, he mostly worked on various projects for power amplifiers, RF filters and multiplexers, communications systems and VHF and UHF antennas.

For over 40 years, Dragan has published articles with different original constructions of power amplifiers, low noise preamplifiers, antennas for HF, VHF, UHF and SHF bands. He has been a licensed Ham radio since 1964. Married and has two grown up children, a son and a daughter.