AMOS

Antenna with Semicircular Radiation Diagram for 2.4 GHz

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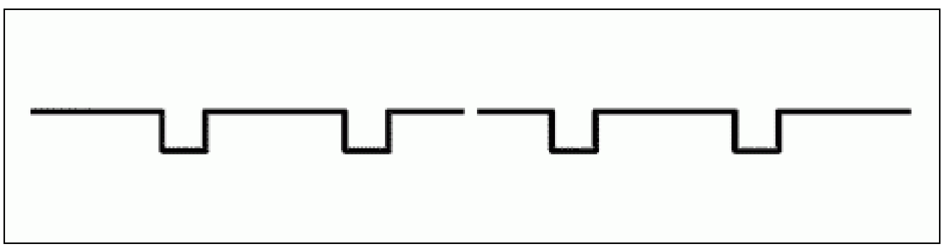
Introduction

In WiFi communications, antennas with semicircular radiation diagram in the horizontal plane are often needed. Antennas with circular radiation diagrams may have gain values as high, as it is possible to narrow its vertical radiation diagram. That's where antennas with radiating dipoles aligned vertically are used. When a circular diagram is needed, and vertical polarization is used, the alignment of half-wave dipoles can be carried out according to the principle of the famous Franklin's antenna.

An open half-wave dipole fed in the middle is extended on both sides with one continuous conductor, which is, every half wavelength, folded into a quarter-wave short-circuited part of symmetrical two wire line. In this way, proper phasing of the half wave dipoles is performed. This kind of wire antenna has been used, mainly in horizontal polarization, from the very beginnings of radio on medium and short waves and is known as Franklin's antenna, after its author.

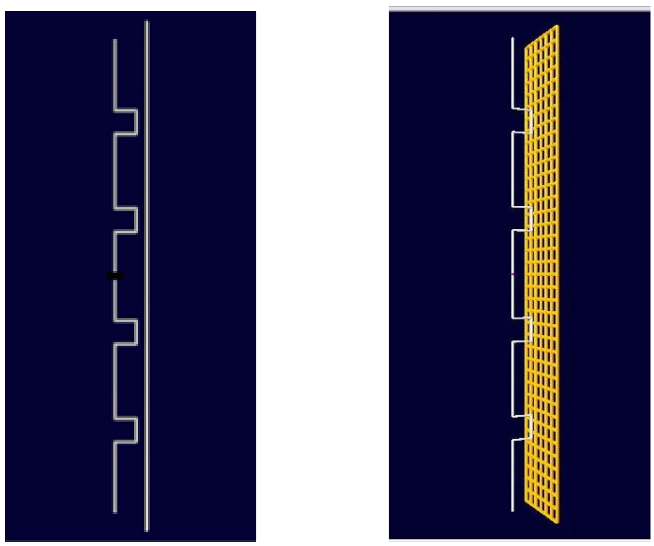


Horizontal Franklin antenna

The problem with impedance and parasitic radiation of phasing lines

This antenna is often used on VHF and UHF bands in vertical polarization, which yields a circular radiation diagram. However, with the increase of frequency, problems arise with phasing lines among dipoles, because they physically enlarge in relation to wavelength, which consequently leads to greater impact of the radiation from this part of the antenna on the overall diagram of the antenna. This unwanted, parasitic radiation of the phasing lines has been resolved in many ways (by wrapping the two-wire line around the antenna axis, by the replacement of the two-wire line with a coil or capacitor, etc.) with more or less success. However, for work on 2.4 GHz, this problem becomes significant also because of the relatively large thickness of the antenna conductors in relation to a wavelength, and therefore the physical dimensions of two-wire line. These dimensions not only determine the characteristic impedance, but also the parasitic radiation of these parts, especially from the short circuit at the end of the two-wire line. (See the figure later in the text marked with **E**). The short circuit at the end of the line needs to be physically very short, so that the great current that flows through it gives as small a level of parasitic radiation as possible. Its shortening decreases the distance between wires in two-wire line, and therefore decreases the impedance of the two-wire line. Even if this decreased impedance is accepted, the physical length of this part of the line can not be short enough not to represent the significant part of a wavelength on this frequency. Therefore, the short wire becomes a considerably efficient radiator of the electromagnetic energy. This parasitic radiation can greatly modify the overall radiation diagram of the antenna.

In order to achieve higher gain from the antenna, a greater number of dipoles needs to be aligned along the vertical. The increase in number of dipoles consequently increases the impedance at the feed point very rapidly and becomes impractically high for simple and efficient supply of the antenna by coaxial cable.

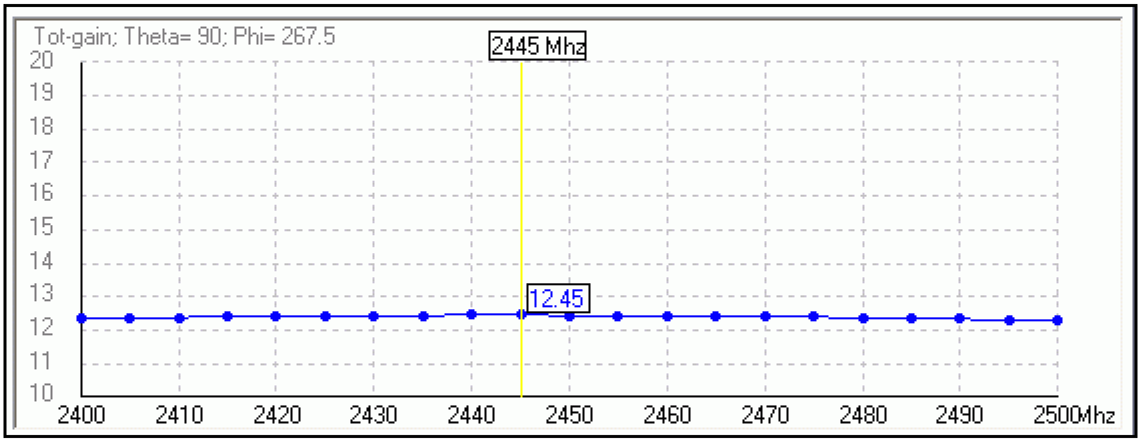


Franklin's antenna with reflector

The solution to the problem with the change of the radiation diagram

However, placing the Franklin's line of dipoles in front of relatively narrow reflector provided solution to these problems, but with the ″sacrifice″ of the circular radiation pattern, which became semicircular. By placing the reflector near the short-circuited end of the two-wire line, the shorting wire and the close reflector act as transmission line with the impedance of about 150 ohms. In that way, the parasitic radiation is considerably reduced. In addition, it was possible to increase the length of that wire to achieve the wanted distance between wires and needed value of characteristic impedance of two-wire line.

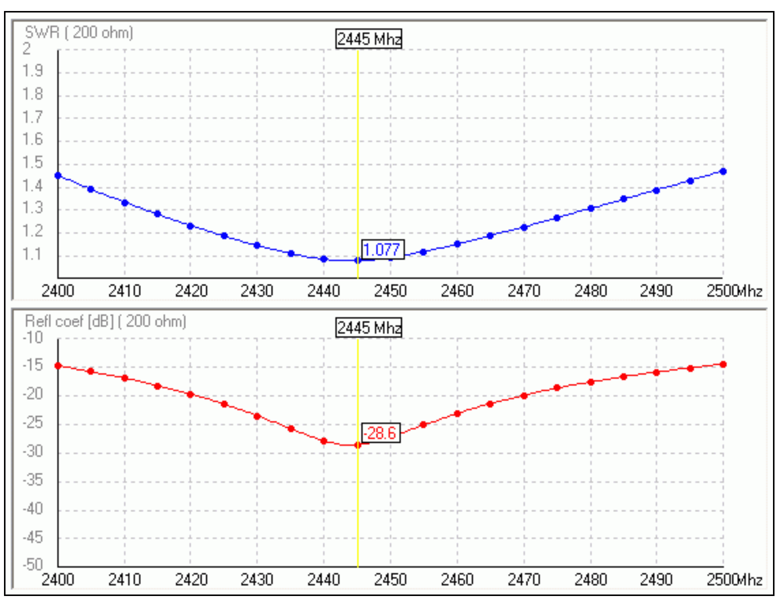
By placing the dipole in front of the conducting reflector plane, the impedance in antenna feed point decreased to about 200 ohms, which enabled very simple and efficient feeding of the antenna by a coaxial cable with characteristic impedanse of 50 ohms through a half wave balun connected as a transformer with an impedance ratio 4:1. The reflector is very narrow, 0.5 wavelengths, so that it narrows the horizontal radiation diagram as little as possible. This yields the Amos antenna.



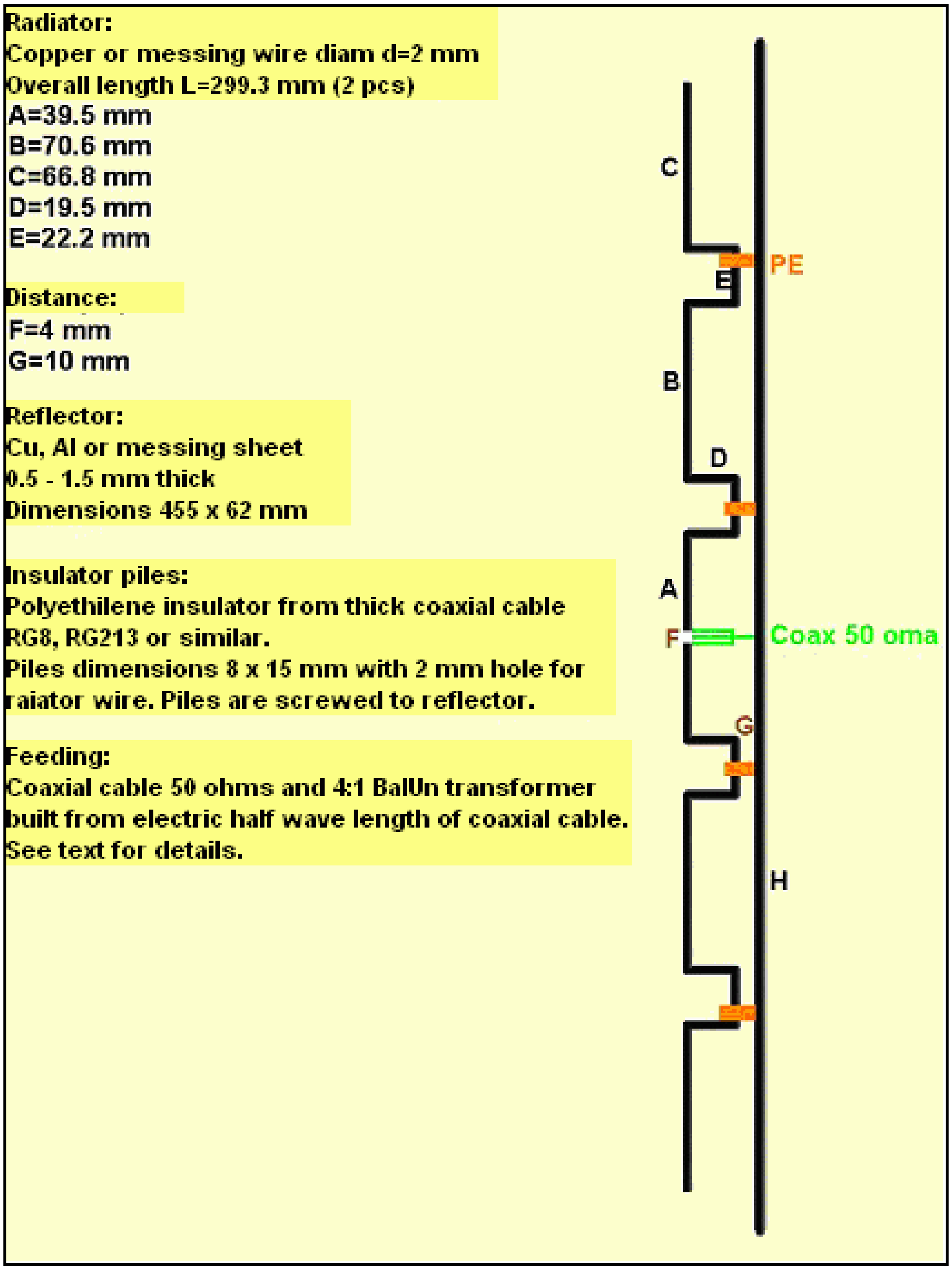
Gain of Amos antenna

Achieved calculated results

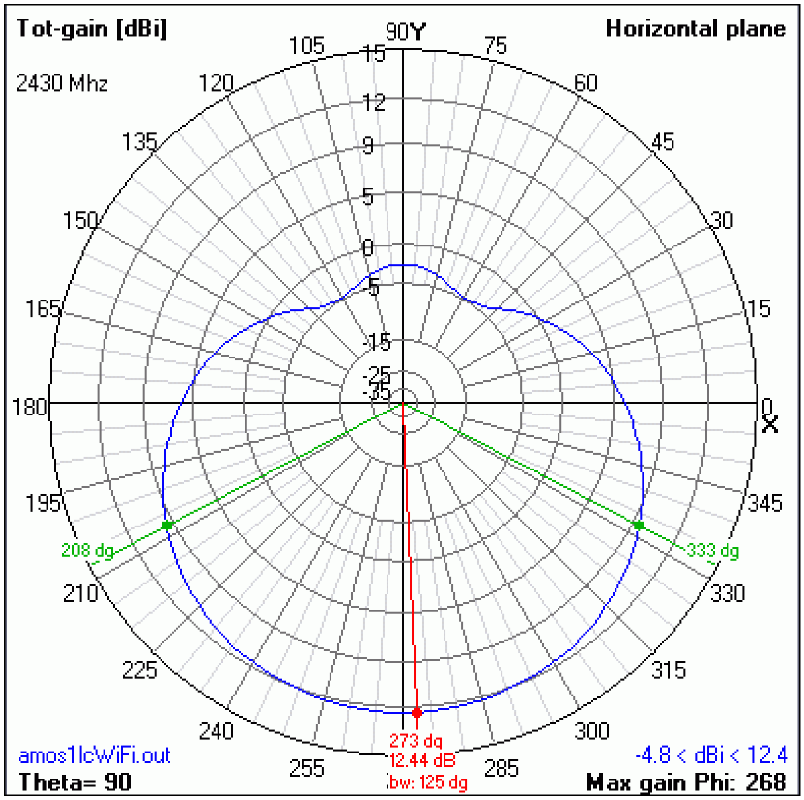
In this way, we achieved antennas with very wide radiation diagrams in the horizontal plane: over 120 degrees for -3dB and about 180 degrees for -6dB decreases of the gain. With very severe symmetry of the geometry of the antenna and the currents within, we achieved very clean diagrams in the vertical plane, with the width of the main beam of 15 degrees and with very good side lobe suppression. The high radiation resistance of the antenna gave a low antenna Q factor and high working bandwidth that can be seen from the antenna input matching diagram. The gain of the antenna of over 12 dBi is very close to the theoretic maximum for this kind of configuration and is completely acceptable for an antenna with this wide radiation diagram in the horizontal plane. This is achieved by careful optimization on the computer, using **4NEC2, a** NEC based antenna modeler and optimizer from Arie Voors.

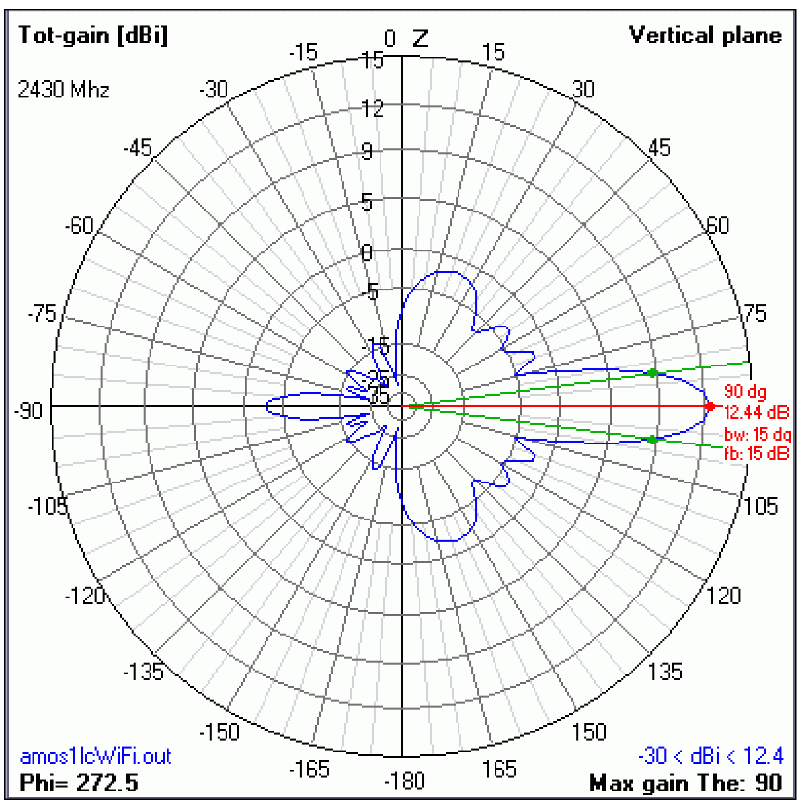


Input matching of Amos antenna

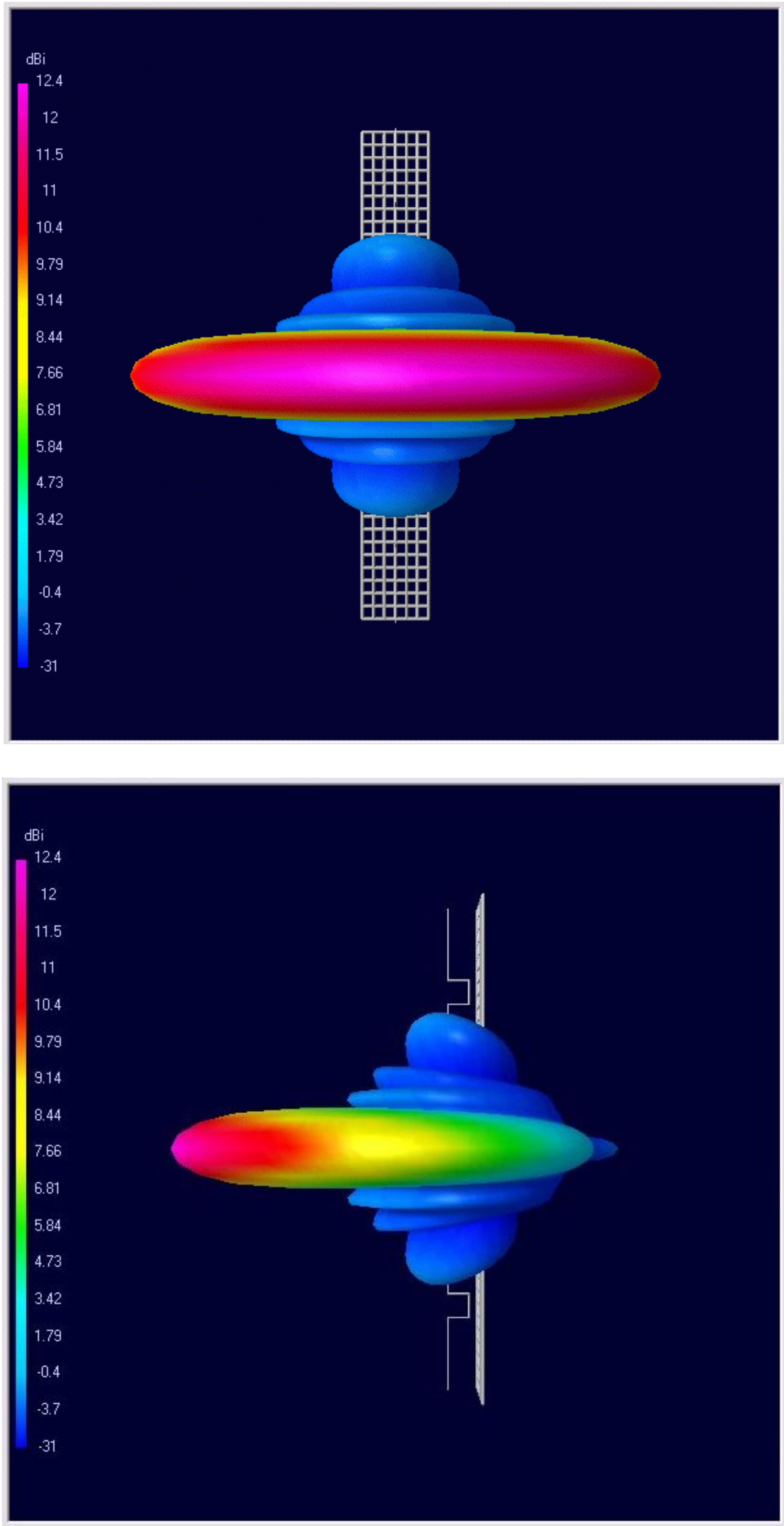


Dimensions and construction of Amos antenna

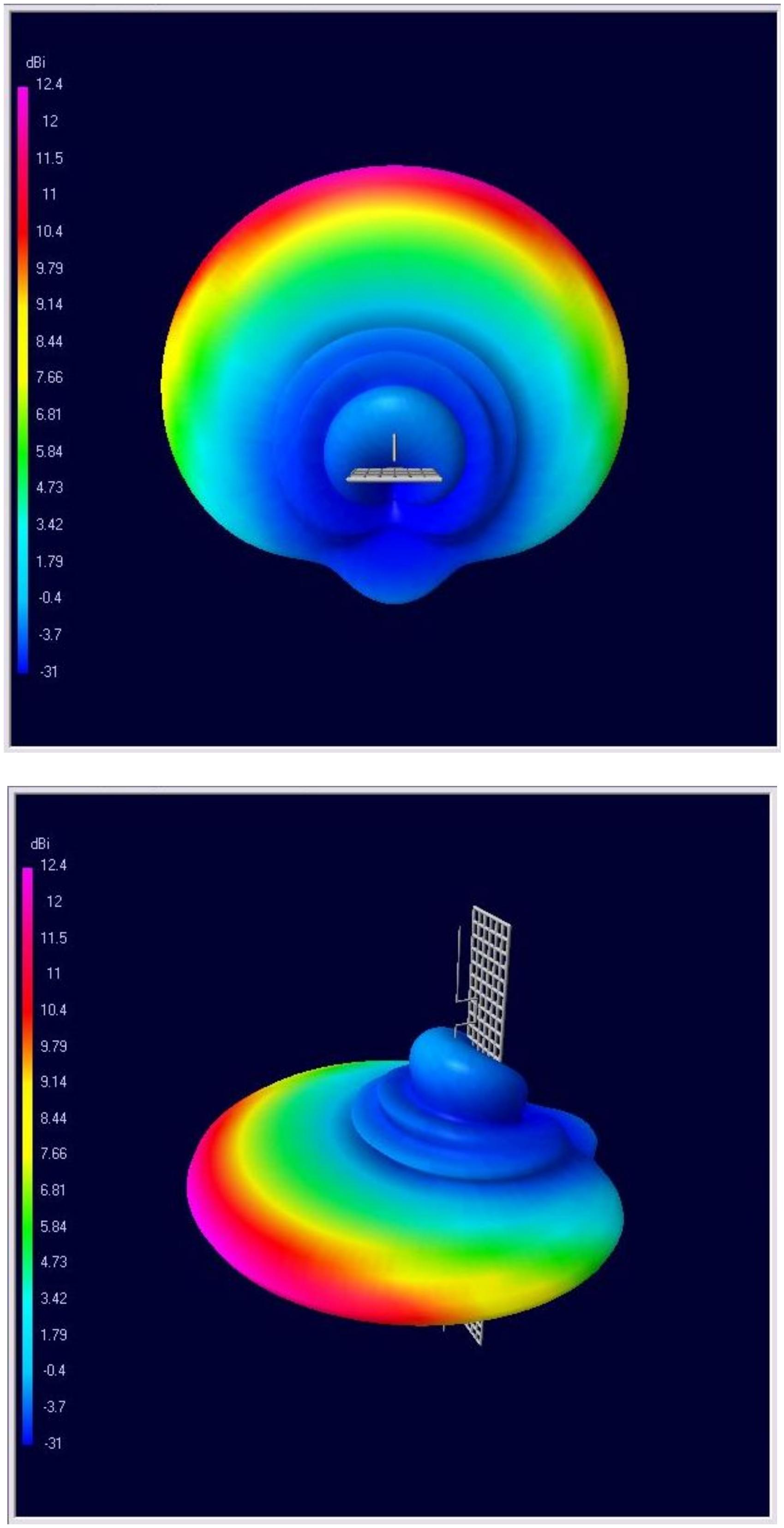




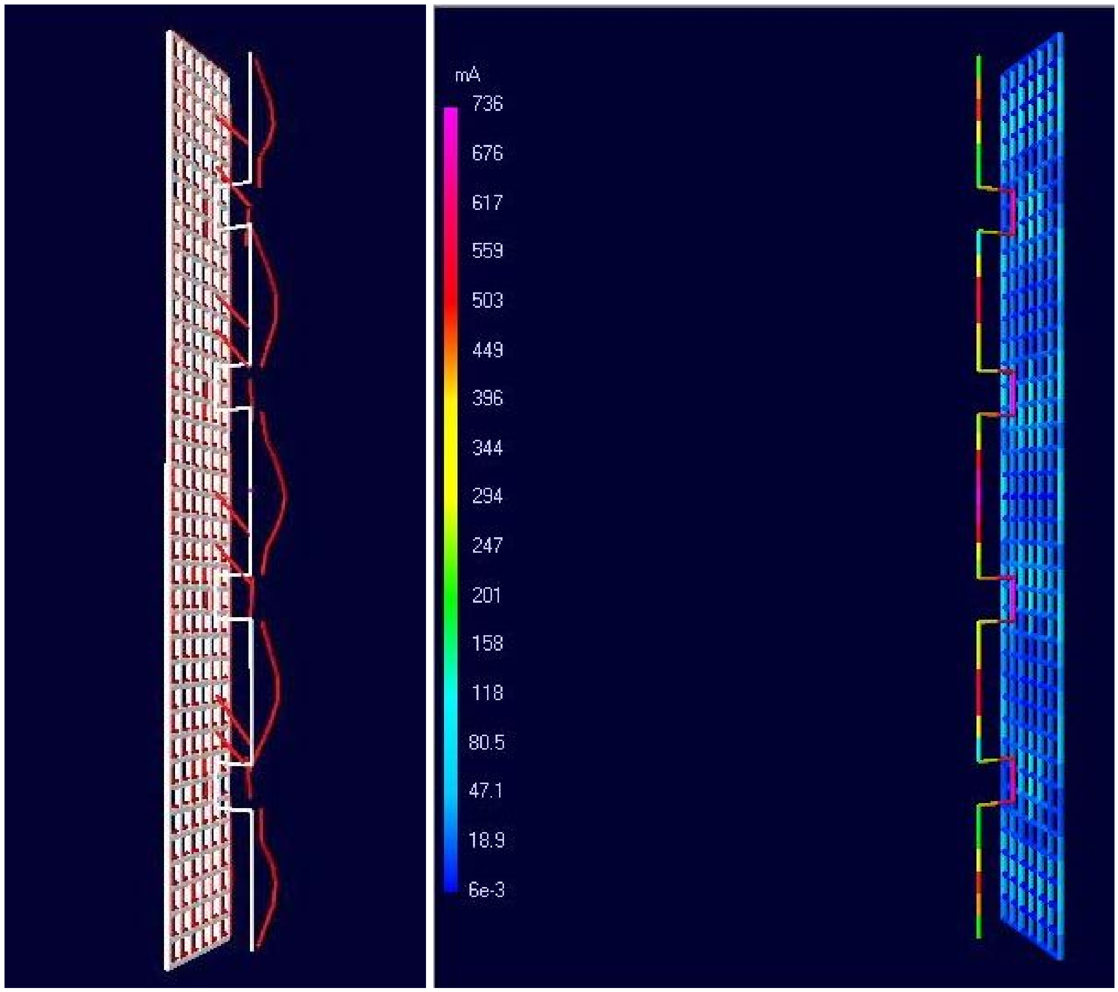
Horizontal and vertical radiation diagram of Amos antenna



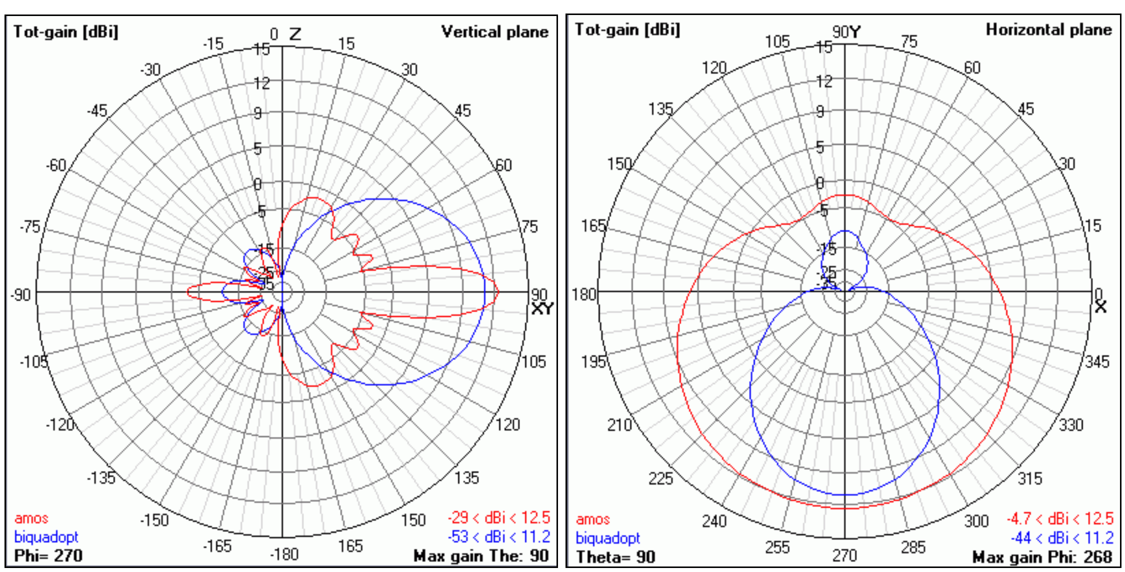
Front and side view of 3D radiation diagram



Bottom and side view of 3D radiation diagram



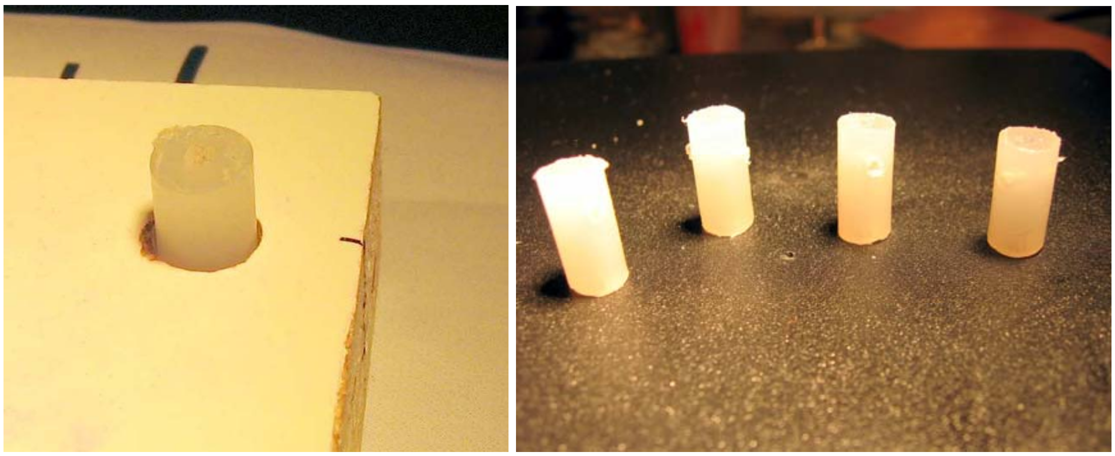
Currents in elements of Amos antenna



Radiation diagrams comparation of Amos and optimal Biquad antenna

Mechanical construction of the antenna

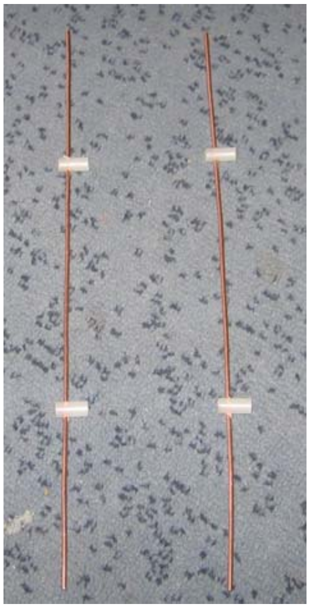
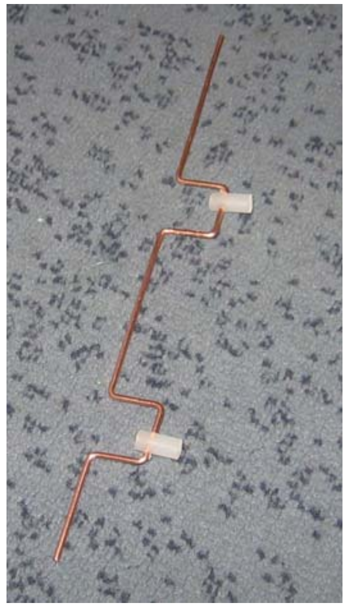
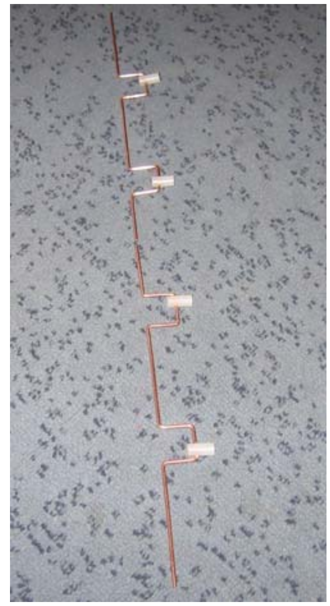
The antenna consists of two copper wires 2 - 2.3 mm in diameter with an overall length of 299.3 mm. Each piece of wire is folded in the same way as shown in pictures. Before folding, measure and cut 299.3 mm long wire, then measure and mark spots where the wire will be folded on the square. Before folding, polyethylene piles should be made and placed on the wire; these piles will serve as isolators and carriers of radiation elements of the antenna.



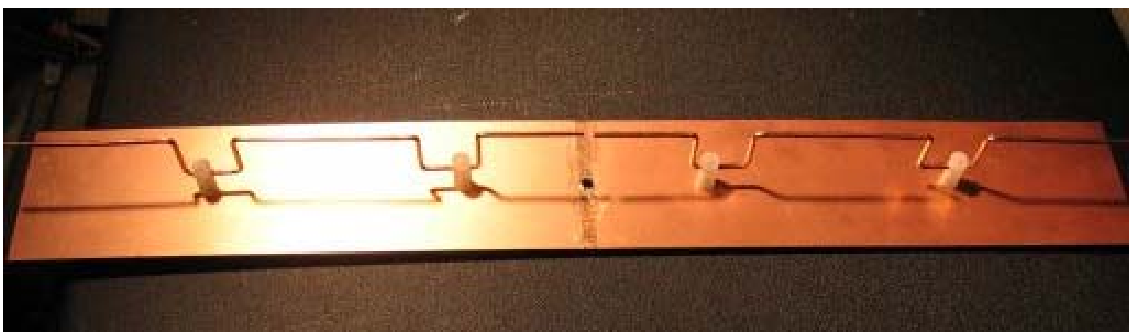
Tool (mold) for making isolating piles.

Piles are made of the insulation from thicker coaxial cables (RG-8, RG213) by removing the inner and outer conductors. The length (height) of the piles is about 15-18 mm, and at exactly 10 mm from one end, the 2-2.5 mm hole should be drilled across the pile through which the wire of the dipole 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 10 mm! The measurement from the surface of the wire to the reflector surface is 9 mm, that is, reduced by the radius of the wire!

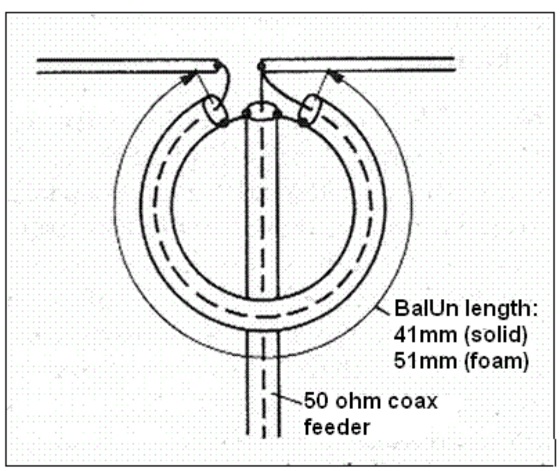
The reflector surface is made of the brass, copper or aluminum sheet metal, 0.5-1.5 mm thick. It may also be made of the single side coppered epoxy; a standard thickness 1.6 mm is usually used for PCB making.

Building of radiating elements of Amos antenna



Fixed radiating elements before balun and feeder soldering



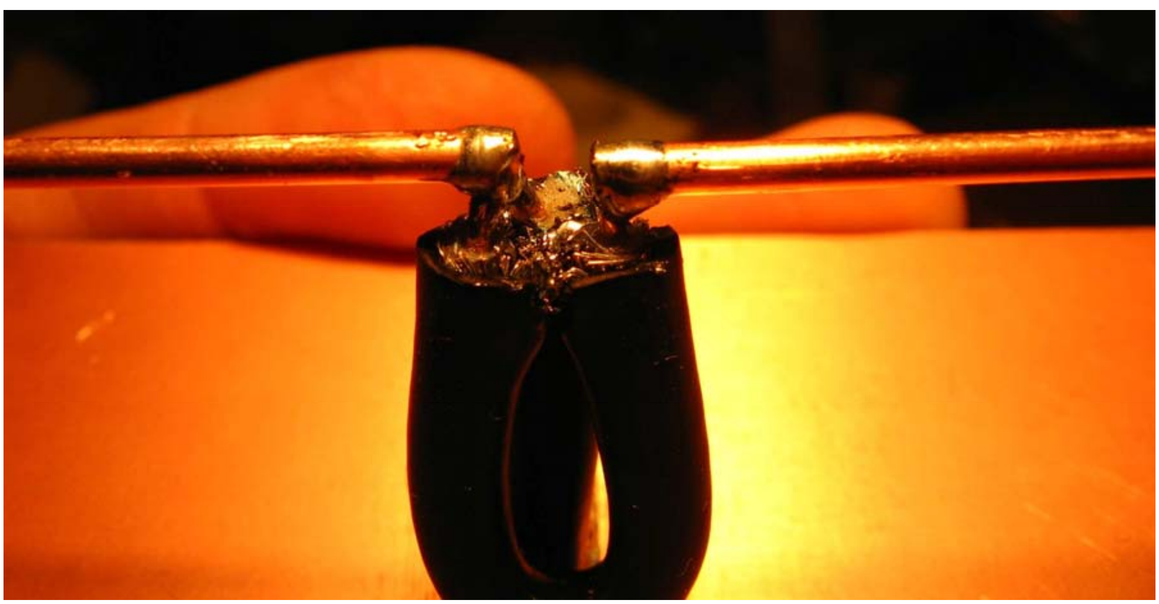
Half wave BalUn connection: its physical length depends on the coaxial cable dielectric type

A hole is drilled into the reflector, 5 mm in diameter, which fits coaxial cable RG-58A, RG-58C or CFD200. The holes for the piles are drilled at 53 and 150 mm from the center, about 3 mm in diameter (depending on the screw used). The cable does not have an electric junction with the reflector surface in the passing through point.

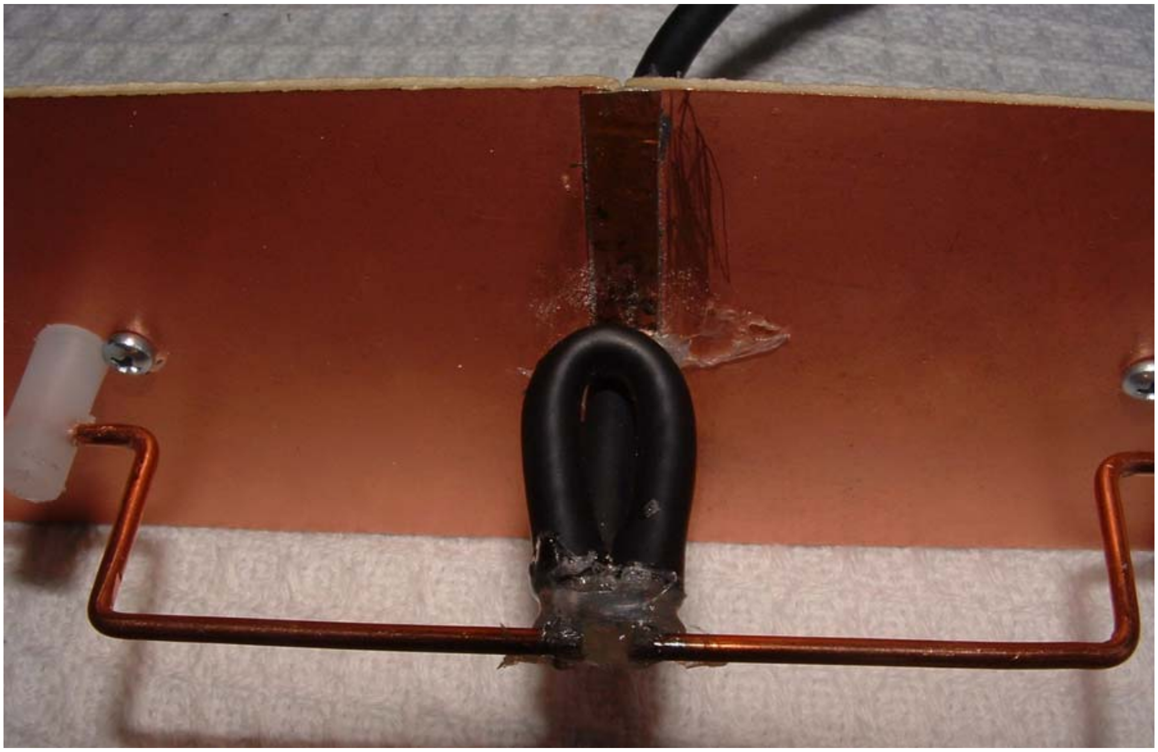
A half-wave balun is made of the piece of coaxial cable whose length depends on the type of the cable! If the cable with full solid dielectric is used, like RG58A type cables, then the velocity factor for that type of cable is vf = 0.66 and the length of the balun is 40.7 mm. But, if the cable with foamy 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 vf = 0.83.

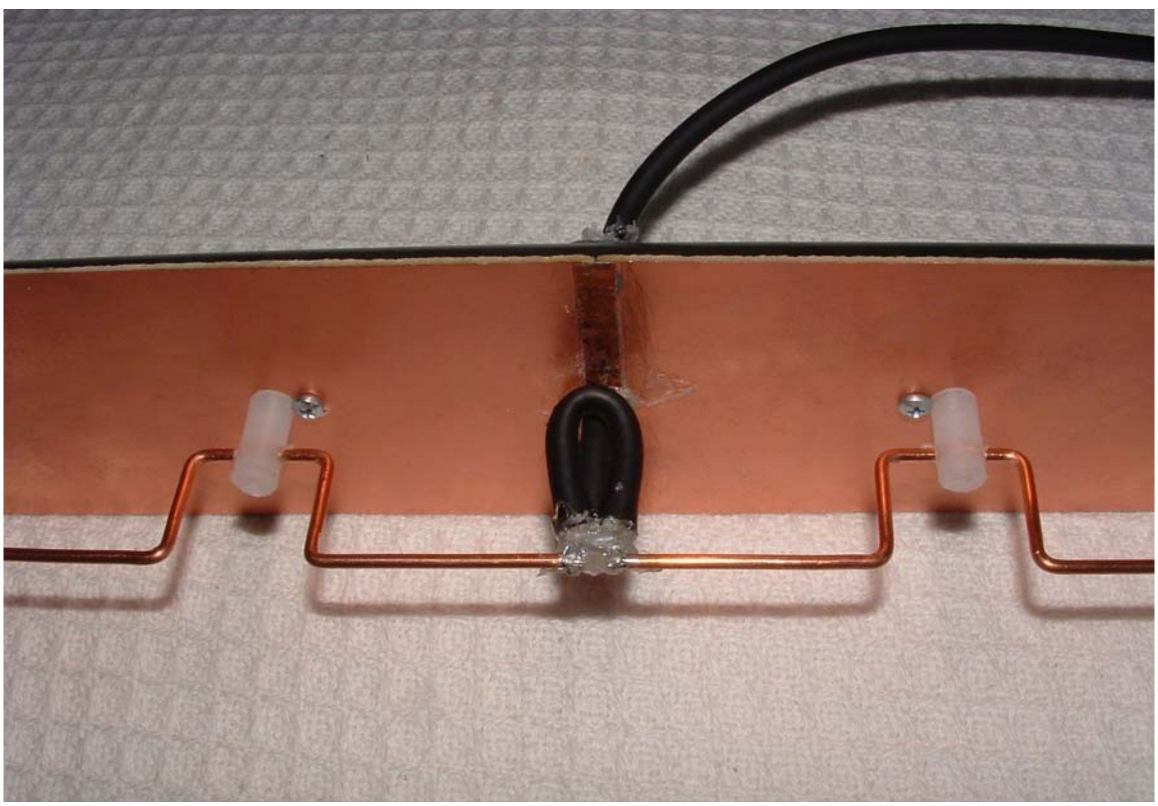
Preparation and soldering of the halfwave balun and coaxial cable

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. Everything should be solder as short as possible in order to avoid shifting the resonant frequency of the antenna due to the parasitic inductances of the connecting wires. The cable endings are placed in the triangle form, so that two ends of the half wave balun are connected to the dipole with the shortest possible leads, and the feeding line placed in the middle is connected with either sides of the dipole. The outer conductors of 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!



Balun and feeder soldered to radiation dipole

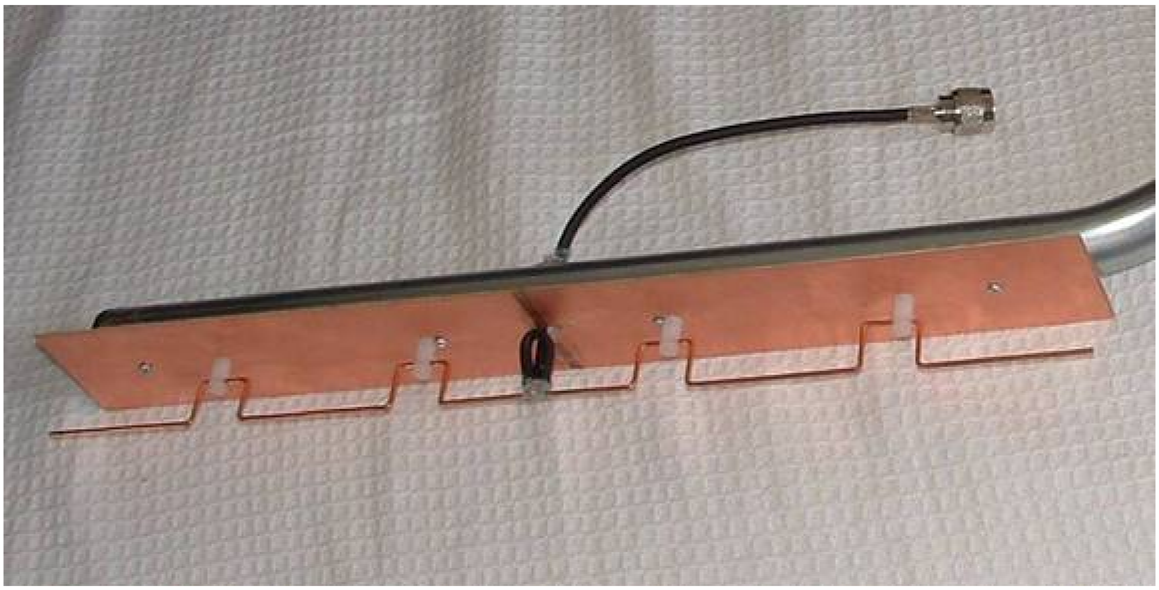




Polyethylene water protection of cables and soldered junctions

The protection from the atmospheric actions

While the copper is still light and corrosion-free, the antenna should be sprayed with the 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 water-proof, 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!



Finished Amos antenna

Alignment for vertical polarization work

Mechanical mounting to the carrier

This mounting 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 wanted direction. The carrier can be made in a way that gives additional strength to 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. For the prototype, a stainless steel rod was used, 25 mm in diameter, bought at the market place already s-shaped. Any metal (especially ferromagnetic) or plastic pieces are forbidden at the front of antenna, near the dipole or the reflector, 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 back side of the reflector surface. The antenna should be moved out in front of the axis of the supporting post for about 15-30 cm in order to decrease the effect of the post on the radiation diagram. If thicker coaxial cable feeding line is wanted, female N connector can be put on the backside of the reflector, and through the hole in the reflector, thin cable can be connected to the balun and dipole. It is not advisable to connect thick cable directly to the balun and dipole, because it is hard to solder it shortly because it is physically bulky, and antenna resonance can be shifted due to parasitic reactances.

Aiming the antenna

During the aiming of the antenna, one should keep in mind that the antenna has a 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 the work with vertical polarization because of its specific radiation diagram in that orientation. The antenna is especially adequate for Access Points due to its great coverage wideness in horizontal plain.

The antenna calculation for other frequencies

The Amos semicircular antenna can be also used for other frequencies if its physical dimensions are recalculated for the new working frequency according to given dimensions in wavelengths:

Wavelength: **Lambda= 299.8 / f(MHz)** **meters**

Overall wire length (in the wavelengths)
L=2.42 (2 pieces)

A=0.320
B=0.574
C=0.543
D=0.158
E=0.180
F=0.032
G=0.081

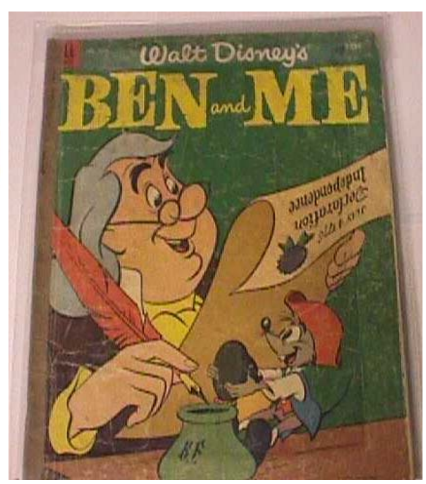
Wire diameter
d=0.0162

Reflector
H=3.70
I=0.50

Half wave balun length
P= 0.5 * v
v= 0.66 for RG58, RG213, RG8 etc.
v= 0.83 for CFD200

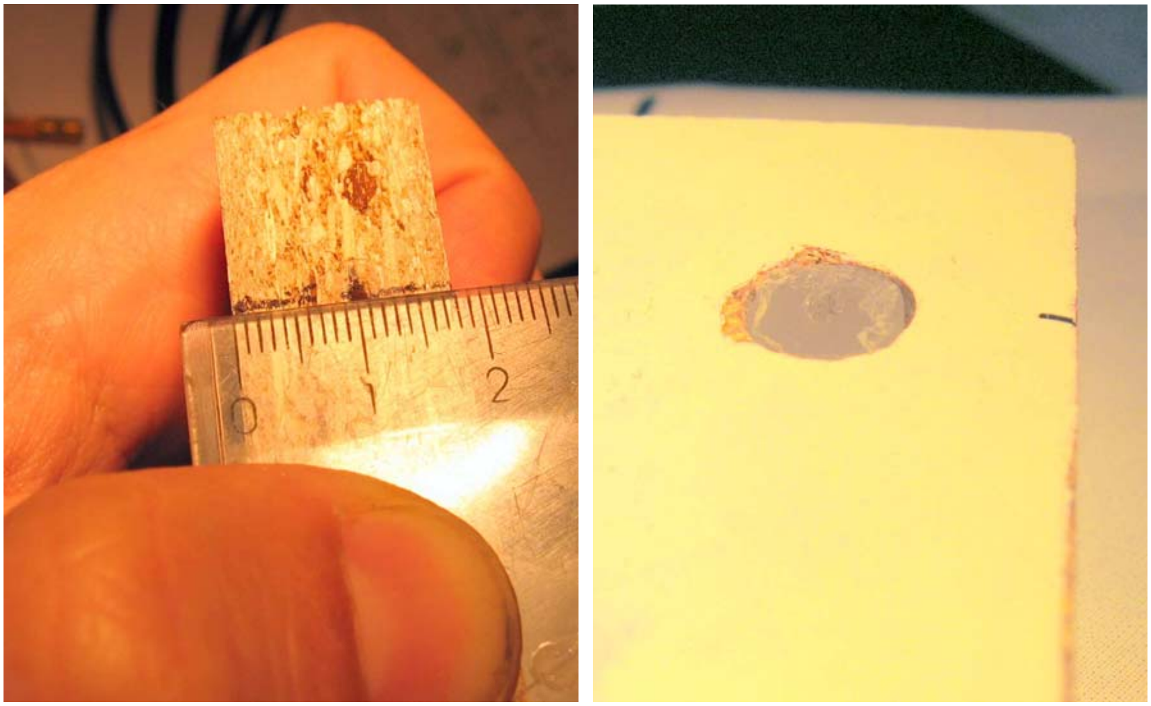
The name of the antenna

The antenna got its name thanks to the completely unexpected associations I had while projecting it. Because it is basically a famous Franklin antenna placed in front of the narrow reflector, which was discussed previously, I thought to name it like that. But that name already has been used for unmodified antenna. The last name ‘Franklin’ associated me to another man with the same last name, Benjamin Franklin, scientist, politician and diplomat, who lived about a century earlier. He was a physicist and inventor who, among other things, flew the kite during the storm and showed that the lightning is actually electricity, invented the lightning-rod, bifocal glasses and famous Franklin stove. But, he also was skilful politician who signed famous Declaration of Independence. Today he is one of the most favorite establishers and 'fathers' of the American state. The anecdotes say he had a mouse for a pet, named Amos. The mouse was named after prophet Amos of the Old Testament, from the small village Tecoa, near Jerusalem, who lived in the 8th century B.C.



Prophet Amos from Tecoa   ***Mouse Amos and Ben Franklin in Disney's cartoon***

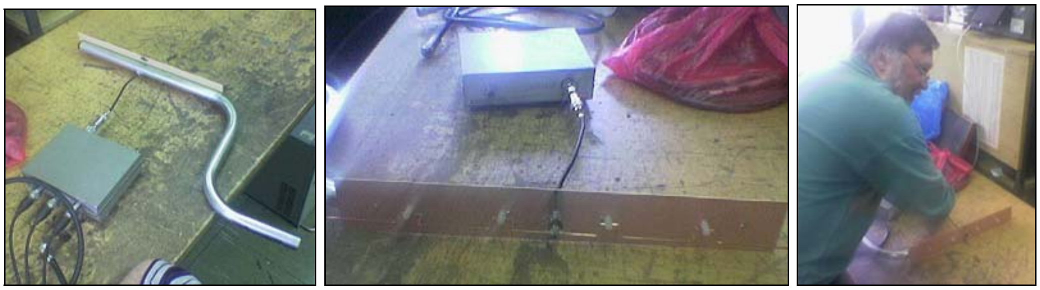
In the 1950s, Walt Disney made a great cartoon based on the novel by Robert Lawson ″Ben And Me,″ about the life and creative work of this great man, and, of course, Amos the mouse is the real star in that movie! That's how this antenna got its unusual name–after one unusual mouse!



Rolex's design of mold for fast and easy piles production

Acknowledgement

I would like to thank my friends from BG Wireless community network for help and cooperation in the realization of this project, and especially to Nebojša Rosić–Rolex, who made, very quickly and precisely, the first specimen of this antenna for measuring. I would like to point out his ingenious tool solution, mold actually, for making isolating piles. The mold is made of piece of plywood sheet, 18 mm thick, with a drilled hole for piles made of the isolator of thicker coaxial cable (RG-8, RG213) by removing the inner and outer conductors. On the side surface, 10 mm from one edge, a 2.2 mm hole is drilled. The plastic is pushed through the plywood sheet, aligned to one side, through the hole on the side the hole for the wire is drilled and before removing the drill, the pile is cut off on the other side. In this way it is possible to make large number of identical isolating piles quickly and easily. In the hole on the side he inserted hollow part of pop-rivet, so the hole wouldn't get wider after a great number of drillings!



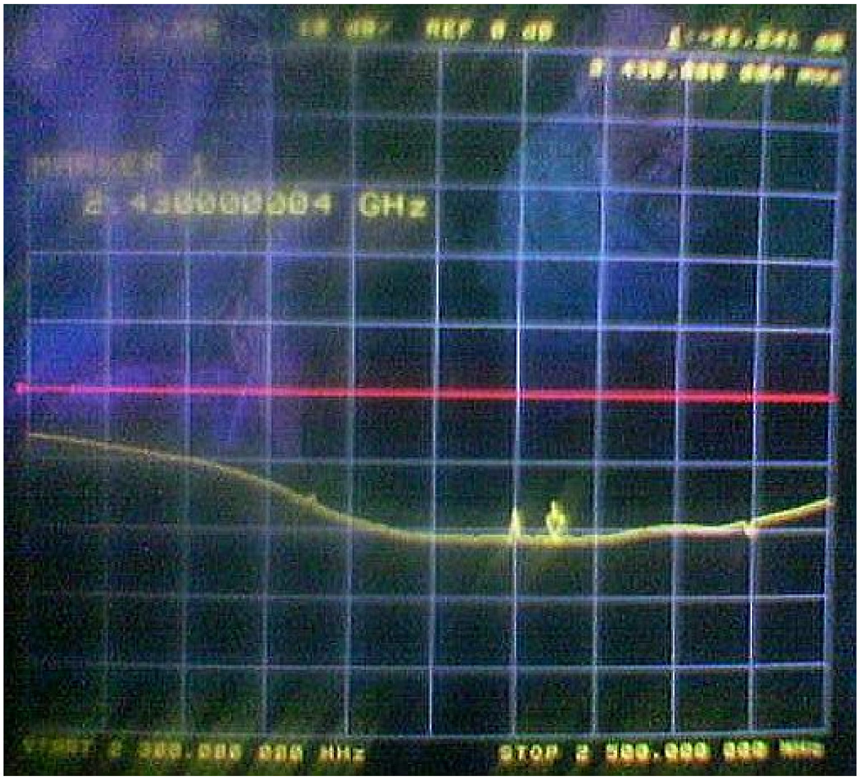
Laboratory measurements of Amos antenna

The laboratory measurements results

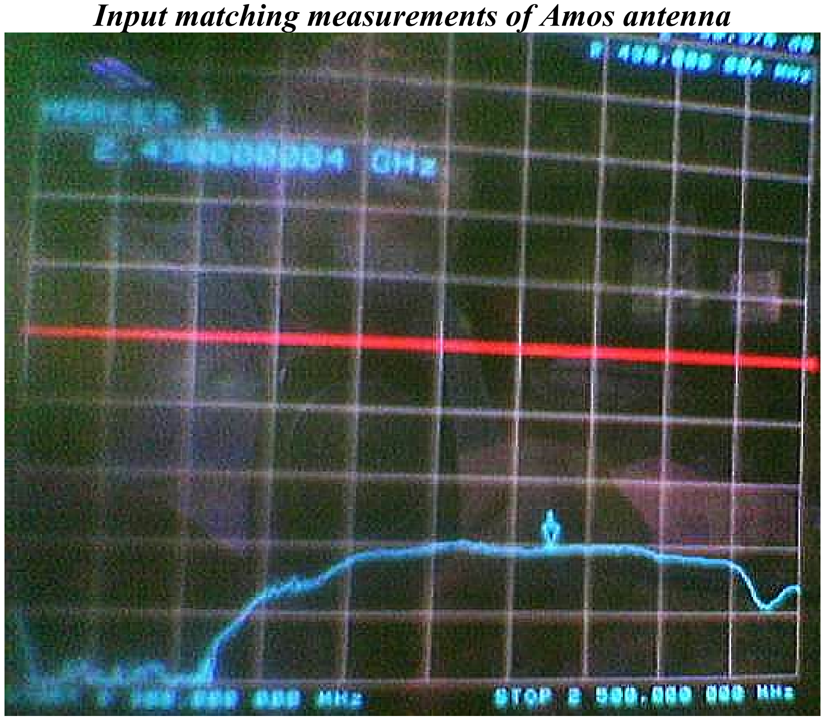
After building, Amos antenna was subjected to the laboratory measurements. The measurements were performed on professional instruments, first of all an HP 8753C Network analyzer. The input matching of the antenna was measured and obtained values showed good correlation with computer predictions. First of all, the resonant frequency of the antenna and the band in which it is matched very well coincided with calculations. The maximum value of the input signal return loss is about -22 dB, which is for about 5-6 dB less than expected, which is partly the consequence of the imperfect measurement conditions, that is, the existence of certain components of spatial reflected wave. The band in which the matching is good is somewhat wider than calculated. This implies somewhat wider frequency working band of the antenna. The gain of the Amos antenna is measured by the method of comparison with known antenna gain, in this case with half wave dipole with gain of 2 dBi. We measured the transmission between radiation and receiving antenna at fixed distance; as a receiving antenna once we used a dipole and the other time we used Amos. While using dipole antenna, transmission was **-30.5 dB**, and with Amos **-19.9 dB**, which gives the gain of **10.6 dB** in relation to referent dipole **of 2dBi**. The results confirmed the gain of Amos antenna of about **12.6 dBi** with possible error of about **+/- 1 dB** because of the imperfect measuring conditions.

The results of the practical work test

Amos antenna is practically compared with earlier built classic corner reflector antenna of about **12dBi** which I use for **WiFi** and the acquired results very well corresponded to the expected ones. The Amos antenna received signals from AP with an almost identical level as the classic corner reflector antenna, which was expected with regard to approximately the same gain. But, the number of received signals was several times higher because of the wide horizontal diagram! Because of this quality, the Amos antenna is designed as an antenna for Access Points! It can also be used for clients when it is necessary to do so, without moving the antenna, to acquire communication with several APs which are located in various directions.



Input matching measurements of Amos antenna



Transmission measurement with dipole receiving antenna

Transmission measurement with Amos receiving antenna

Conclusion

In this work we demonstrated and confirmed by measurements the possibility of using Franklin's line of half wave dipoles in front of a relatively narrow reflector surface as an efficient antenna on 2.4 GHz. The antenna has a vertical polarization and semicircular radiation diagram in horizontal plane. The problem of parasitic radiation of parts of two wire short-circuited lines for phasing is resolved by placing the reflector surface near short-circuit conductor; in that way, the conductor was transformed into a transmission line with an impedance of about 150 ohms and 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, using 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.

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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.