Printed Omni Directional Wi-Fi Antenna for 5.6 GHz

Dragoslav Dobričić, YU1AW
dragan@antennex.com

Why printed antenna?

Building antenna on SHF is associated with problems of manufacturing its parts with high accuracy that is demanded by very small working wavelength. Every mechanical work is subjected to some tolerances that can be kept and if they have to be very tight then problem of reproducibility arises if more than one antenna has to be built.

Machine work can improve accuracy of built antennas, especially CNC machines, but unfortunately sometimes there are some specific limitations in using these machines for partial or complete antenna production.

On the other hand, there is printed circuit technology that uses photography technique and can achieve very high precision of printed circuit pattern. Reproducibility in this technique is very easy and very accurate so it seems like a perfect technique for producing SHF antennas.

The problem which often limits this technique to be applied for antenna building is higher RF loss in printed antenna board substrate than in the air. For high quality substrates with low loss and good mechanical properties, price can very often be unacceptably high.

Another problem can be very thin copper layer which also can have higher loss due to the conductor's small cross section area. This very thin conductive layer is also very limited in amount of RF power that can be applied to antenna.

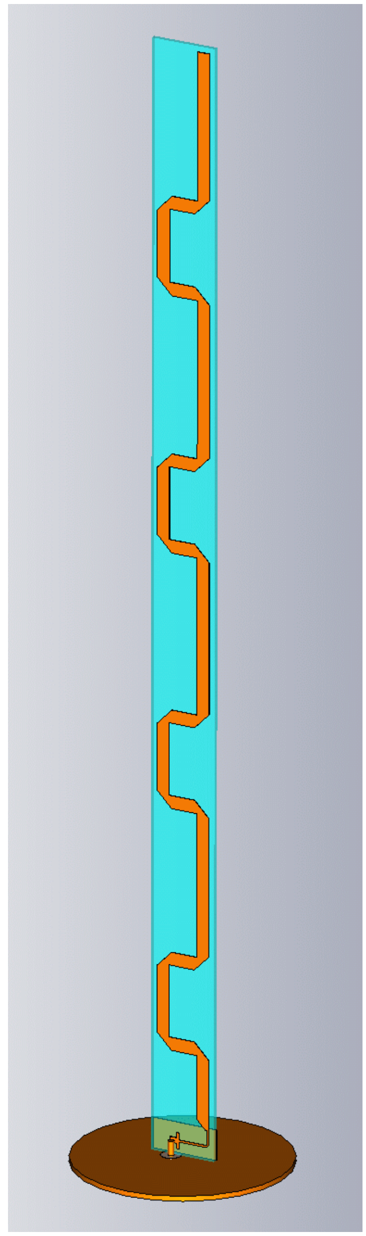


Fig. 1 Printed antenna

In the last several years many manufacturers of RF PCB laminates were producing good and cost acceptable materials especially intended for PCB antennas. That is because PCB antennas today are widely used in many mobile phones and other small mobile radio gadgets equipped with very tiny printed antennas.

Printed antenna for 5.6 GHz

In one of my past articles I explained how Franklin's collinear dipole array can be used as a sector antenna where parasitic radiation of shorted circuit ends of phasing lines are suppressed by converting them into transmission lines close to the reflector surface **[1]**. However, in another article I showed how these shorted circuits phasing lines end and its parasitic radiation can be exploited as a constructive part of radiation structure and improve directivity of a collinear antenna **[2]**. Such possibility opened the opportunity to construct an omni-directional antenna by simple removal of reflector surface and keeping constructive interference of dipoles and phasing line shorted circuits end radiation.

Armed with previously acquired experience and exceptional success of antennas published in these two articles in practical work, I decided to try to rebuild them into antennas made in PCB technology.

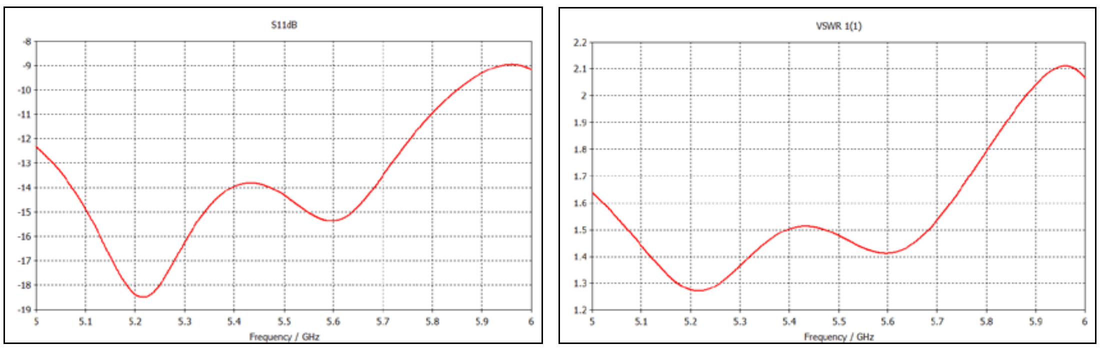


Fig. 2 Input return loss and VSWR of omni-directional printed antenna

Removing the reflector plane raised problem of feeding dipoles in the center of the antenna with coaxial cable that is coming vertically from the antenna's bottom. A vertically polarized antenna and coaxial cable which is parallel with the polarization vector and additionally is very close to radiating elements, usually produces a high influence to antenna impedance and radiation pattern distortion.

The only way to minimize these effects is to move the feed point at the most bottom point of the antenna. This means cutting the antenna in half and replacing the bottom part by a suitable ground plane mirror. At the bottom of the antenna dipole array, between a connector mounted on a ground plane disk and lowest dipole, there is a simple printed matching network consisting of various lengths and impedances of microstripe transmission lines.

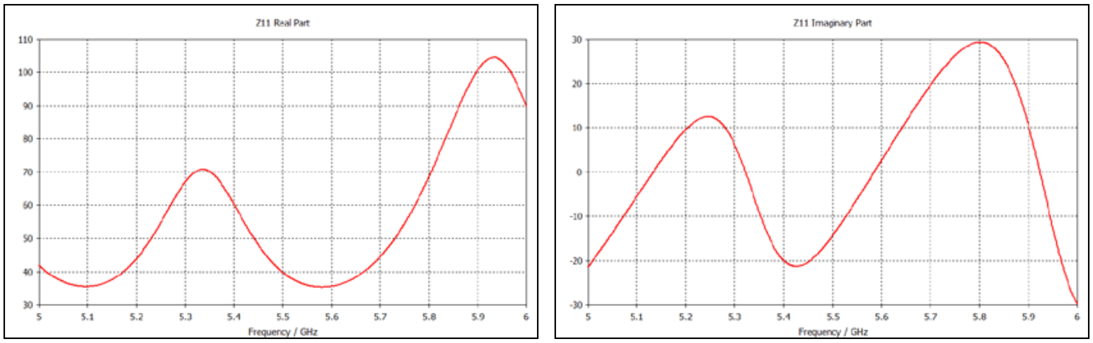


Fig. 3 Real and imaginary part of printed antenna input impedance

In this way antenna construction becomes very simple and easy. Only three elements constitute the whole antenna: printed dipoles board, ground plane board and connector. It is not necessary to tune or adjust the antenna in any way. All antenna parameters are carefully optimized, with a very small number of inevitable compromises, by one of today's top professional antenna software **[3]**. Obtained simulation results are given in the figures presented herein.

Antenna input return loss

As can be seen in Fig. 2 and 3, very good input return loss is achieved in a pretty wide bandwidth. In many countries, Wi-Fi band is between 5.2 and 5.8 GHz. Also, around 5.6 GHz there is allocation of amateur radio service. So, besides Wi-Fi, this antenna can be used also for low power amateur radio repeaters and everywhere where omni-directional an antenna with a gain of about 9 dBi satisfies the requested antenna parameters.

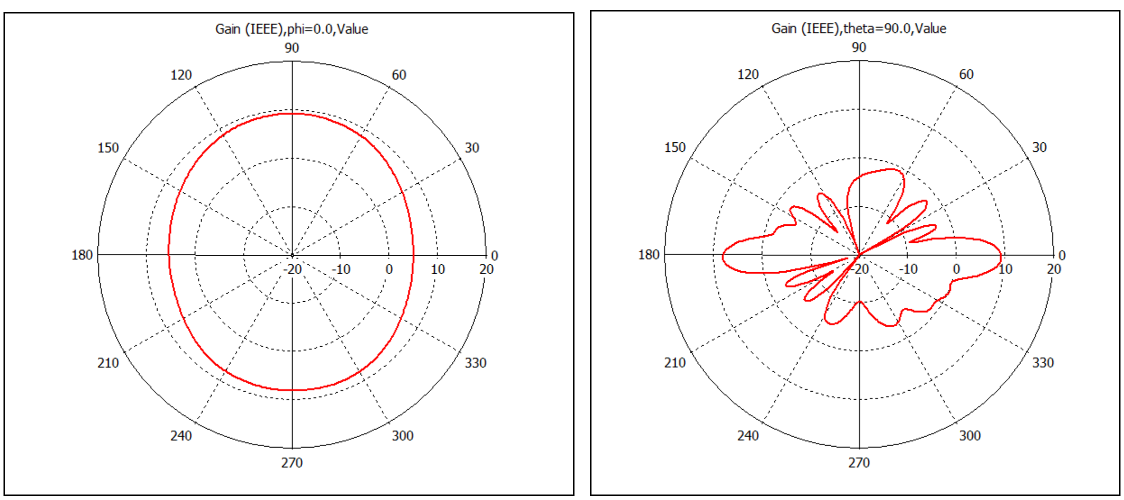


Fig. 4 Horizontal (left) and vertical (right) plane radiation pattern of printed antenna

Antenna gain and polarization

The gain of an omni-directional antenna can be obtained only from narrowing the antenna's vertical radiation pattern. To have a high gain omni-directional antenna, it is necessary to have a very narrow vertical radiation pattern. On the other hand, a very narrow vertical pattern is not suitable for covering an area where all correspondents are not on the approximate same height, i.e. they don't lie in the same horizontal plane. This represents the practical limitation of usable gain for every omni-directional antenna.

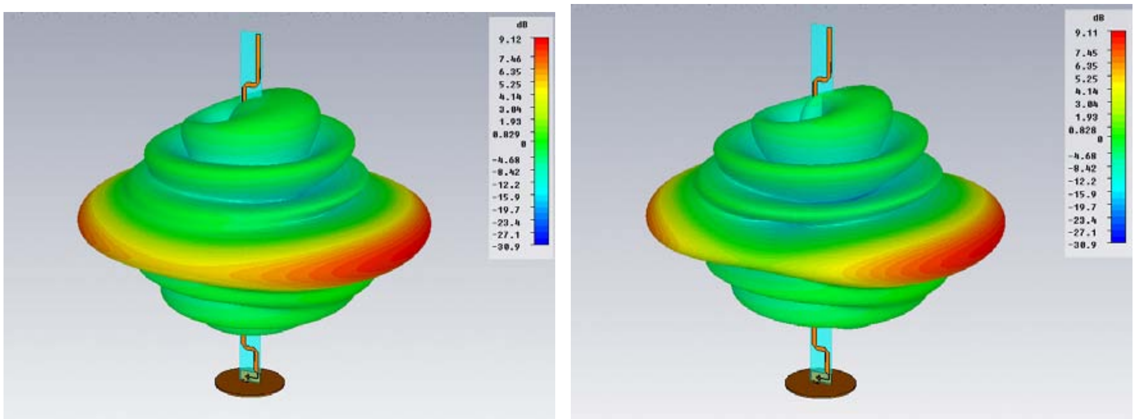


Fig. 5 Absolute (left) and Vertical (right) polarization far field component of printed antenna

In this type of antenna, there is another theoretical and practical limitation in the number of dipoles used and thus in obtainable gain of antenna. The gain of a collinear antenna increases for about 3dB for every doubling of dipoles used. But there is rapid decreasing of current which flows through every subsequent dipole going from feed point to the end of a dipole array. Finally, once a certain number of dipoles is reached, further attempts to increase gain with more doubling of dipoles reaches a point of saturation and a point of no return is reached as to more gain.

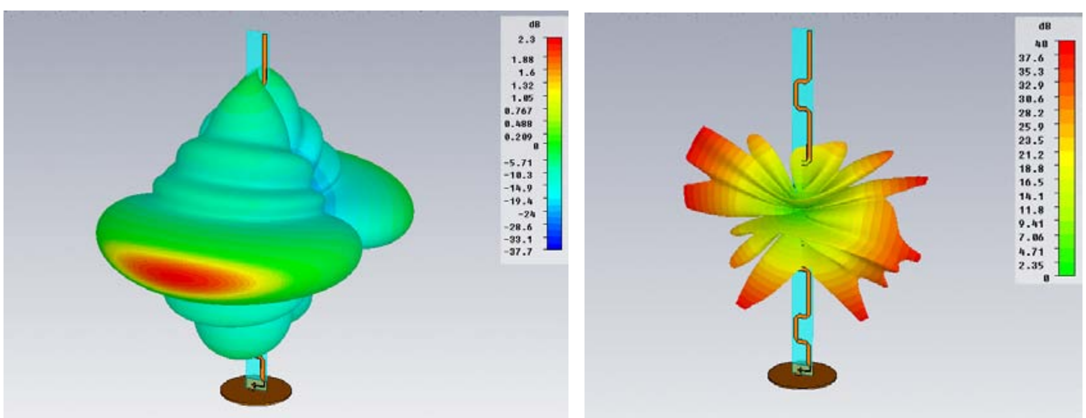


Fig. 6 Horizontal polarization far field component (left) and Vertical to Horizontal polarization far field ratio (right)

Vertically oriented dipoles and shorted circuits of two wire phasing lines radiate vertical polarization. Phasing lines itself are balanced and shouldn't radiate. But due to imperfect current balance and influences of other conductors carrying substantial currents in their vicinity, phasing lines also radiate some amount of energy and its polarization is horizontal. Maximum of their resultant radiation is in direction normal to printed dipole board plane as it is visible on the left side of Fig. 6. It means that antenna has an omni-directional pattern and vertical polarization but there are also two regions with additional horizontal polarization radiation.

Cross polarization radiation of antennas is something inevitable and very often it is necessary to make substantial effort and lot of compromises to minimize it, i.e., to improve ratio of horizontal to vertical polarization far field values. This cross polarization ratio value is different for every particular direction as can be seen on Fig. 6, right side.

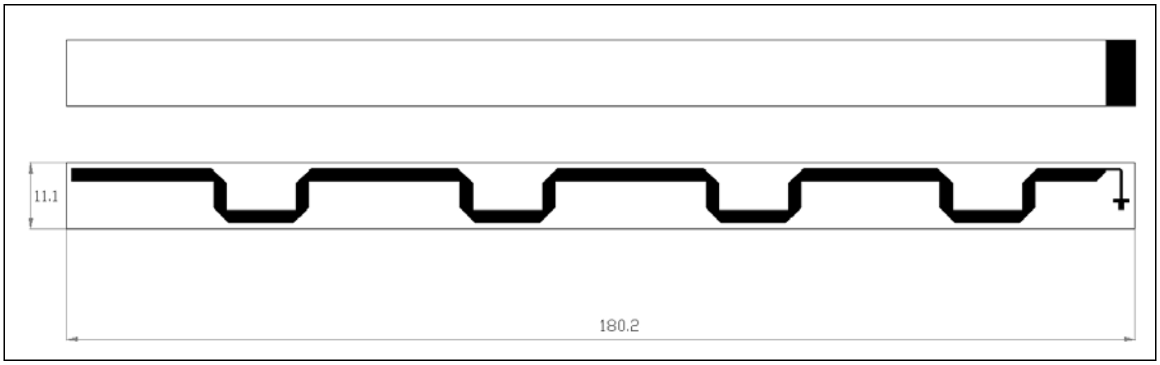


Fig. 7 Front side layout of dipole array and back side with ground patch

Practical realization

The antenna is optimized for antenna grade laminate RO4534 from *Rogers™* that is specifically engineered and manufactured to meet the specific demands of the printed circuit antenna applications in UHF and SHF bands **[4]**. Used substrate has approximately more than 50 times less dielectric losses than usual FR4 substrate. This ceramic-filled, glass-reinforced hydrocarbon based material set provides the controlled dielectric constant, low loss performance and excellent passive intermediation response required for mobile infrastructure microstripe antenna applications. Important feature of this substrate are homogenous, tight and repeatable characteristics that are very important for antenna's proper and predicted work.

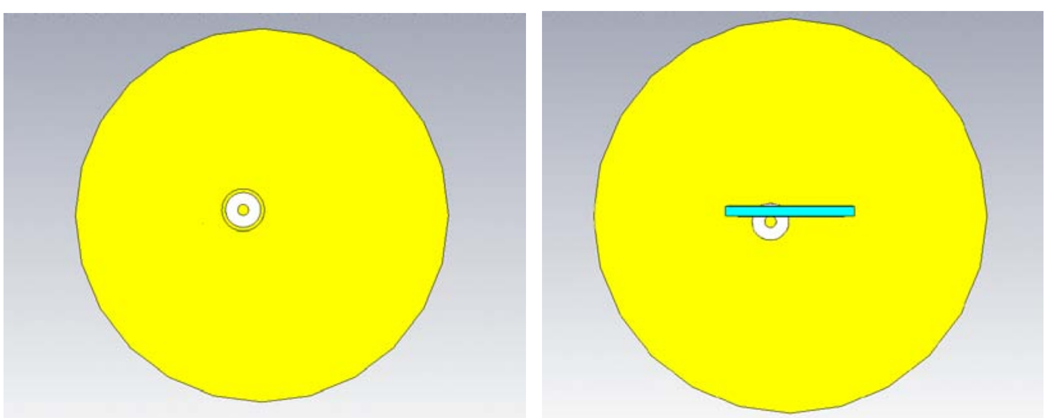


Fig. 8 Layout of ground plane with disk top and bottom view

The dipole array was printed on standard RO4534 board whose overall dimensions have to be quite accurate 180.2 x 11.1 x 0.81 mm. The copper layer is one ounce or 0.032 mm thick. On the front side there are 4.5 half wave dipoles with suitable shorted circuit two-wire transmission lines which serve as phasing lines. Shorted circuit ends of phasing lines also serve as a constructive part of the antenna radiation structure similar as in an antenna described in my past article **[2]**.

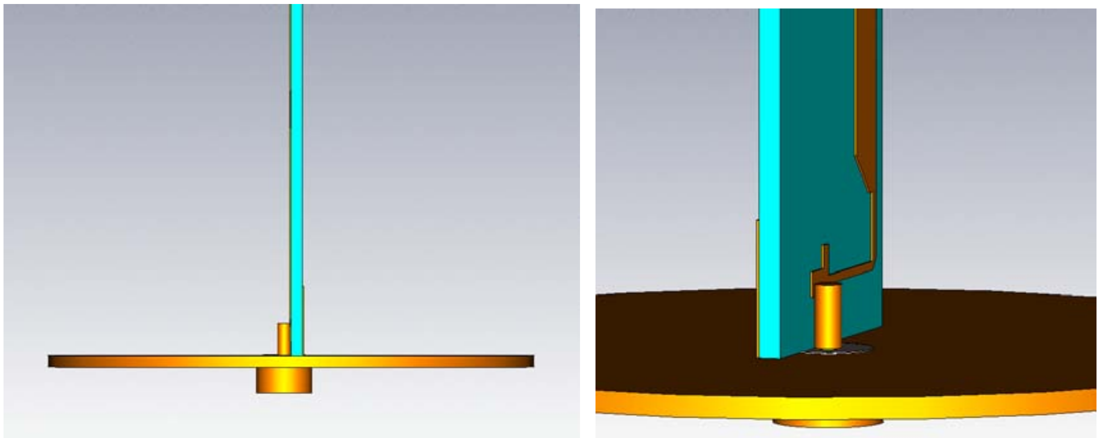


Fig. 9 Layout of ground plane disk, connector and dipole array from side views

On the back side of the dipole array board there is printed ground plane “patch” for antenna input impedance matching microstripe lines. This ground plane is also used to mechanically reinforce the antenna by soldering the bottom line of this patch to the antenna ground plane disk under the right angle. Together with soldering of the connector pin to antenna feeding point, this improves assembled parts overall strength.

The ground plane disk is also made of PCB laminate whose copper clad serves as conductive reflecting mirror. Disk radius is 17.5 mm (35 mm diameter) and SMA, RPSMA, MMCX or other suitable miniature connector type is pushed through drilled hole prepared in advance and soldered to disk so that both board copper layers are soldered to the connector’s ground. Central pin of the connector is directly soldered to feeding point of antenna as is shown in Fig. 9.

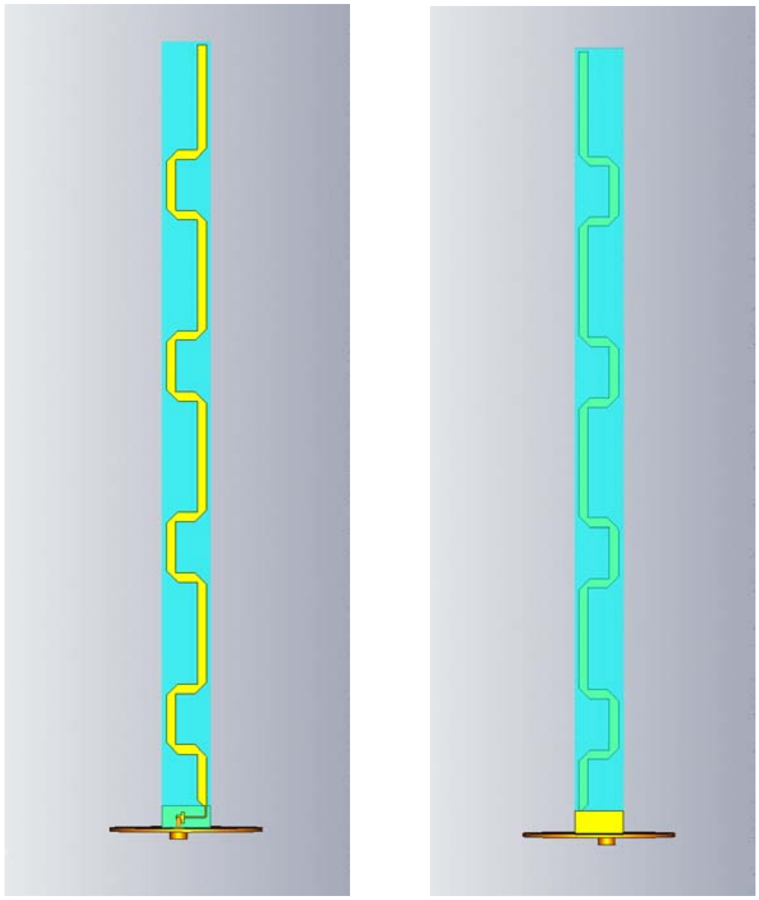


Fig. 10 Appearance of antenna from front and back side

For weather protection the whole antenna can be placed into a suitable plastic tube radome with walls as thin as possible and low dielectric permittivity and losses in order to minimize tube radome influence on the antenna's radiation pattern and input impedance.

Conclusion

In this paper I described printed omni-directional antenna as a derivation of my earlier works on Franklin's collinear dipole array. Using today's antenna grade laminate at a reasonable price, it is possible to get low loss and thus a high efficiency printed antenna on SHF frequencies. Simplicity and excellent reproducibility, together with high gain and broadband match to 50-ohm coaxial cable, are the main features of this small antenna.

Warning:

Please do not try to build this antenna on usual FR4, G10 or any other similar PCB laminates which are not antenna grade laminates! Different dielectric permittivity of substrate dictates different dimensions of printed antenna! Poor homogeneity and much higher dielectric losses of these materials make them unsuitable for printed antennas on SHF frequencies. Results, very probably, would be a complete disappointment!

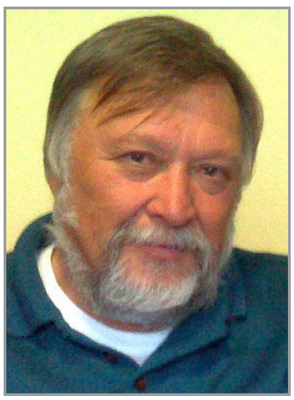
-30-

References:
1. Dragoslav Dobričić, YU1AW, **Amos Antenna,** *antenneX* issue No. 127, November 2007.
2. Dragoslav Dobričić, YU1AW, **Inverted Amos Antenna,** *antenneX* issue No. 130, February 2008.
3. Computers Simulation Technology AG., www.cst.com
4. Rogers Corporation, Rogers' Antenna Grade Materials, http://www.rogerscorp.com/documents/888/acm/RO4500-Antenna-Grade-Laminates-for-High-Volume-Applications.aspx

---

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



professional 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. He is married with two grown up children, a son and a daughter.

antenneX Online Issue No. 158 — June 2010
Send mail to webmaster@antennex.com with questions or comments.