Yagi Antenna Improvement
Thirty-Year Old Dead End?

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Introduction

Performances of Yagi antennas very often degrade when they become wet. In my previous article [1], I show how Yagi antennas behave under moist conditions. All of the antennas behave very similarly, tending to shift their performances lower on the frequency. However, those antennas that have good margin to the gain drop point, where the antenna's working frequency approaches a critical frequency, at which rapid gain decrease starts due to improper currents phasing in antenna passive elements, still preserve their good performances under the wet working conditions.

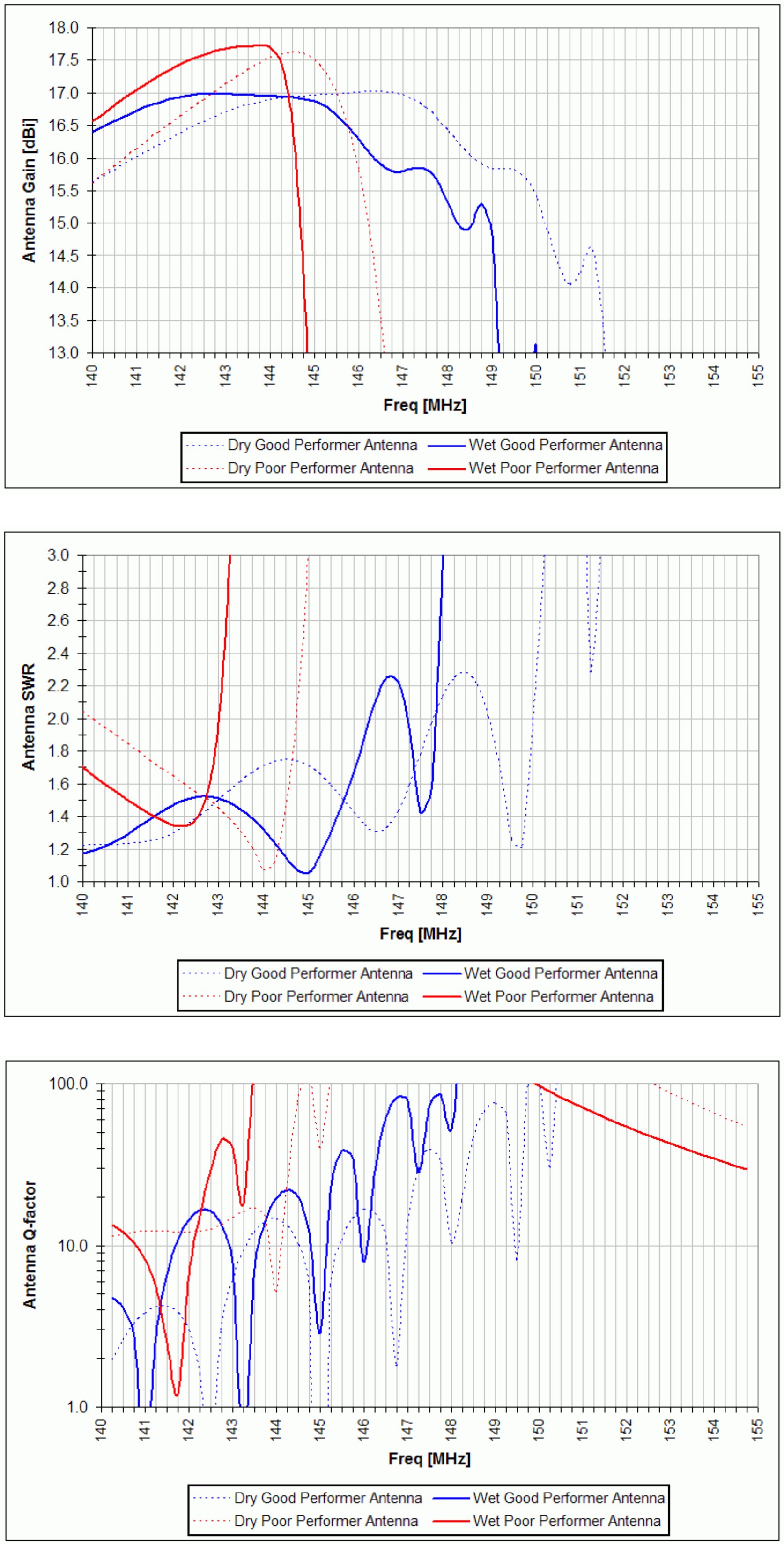
The diagrams show the behavior of a good and a poor performer antenna under dry and wet working conditions.

In the conducted simulations, I opted for "water foam" relative dielectric permittivity of Er=8 and thickness of 0.5 mm according to practical observation in order to improve accuracy of my previous simulations and to ensures fair enough comparison between antennas.

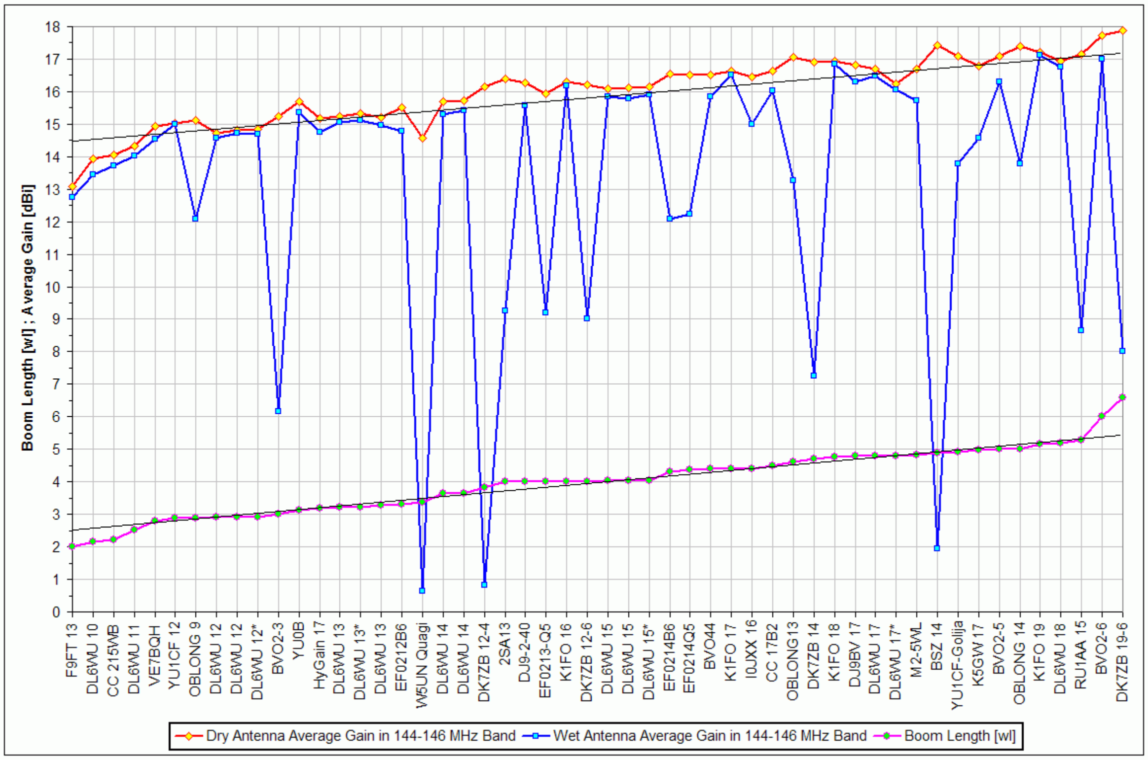
Some difficulties in right choice of water thickness were raised because of different antenna elements diameter. Quantity of accumulated water on elements likely depends on its diameter. Water thickness on elements produce influence on performance that is dependent on R/r**,** where **r** is bare wire radius and **R** overall water covered wire radius. Ratio of these two radiuses R/r is important for wet antenna performance [2, 3]. It means that the antenna with thicker elements, for the same water film thickness, would have lower R/r value and thus lower equivalent loading distributed inductance L than the antenna with thin elements and higher R/r ratio.

As a result, when the same water thickness collects on their elements, antenna with thicker elements would probably produce less frequency shift than the similar antenna with thinner elements.

In my next article I will try to give some more thorough analyzes of this problem.



Dry and wet gain, SWR and Q-factor of good and poor performer Yagi antenna



Boom length and average gain of dry and wet Yagi antennas of various experimenters

Analysis of the results

The analysis of the results can be conducted in many different ways depending on the antenna performances which we choose as the most important for our purpose.
The boom length of Yagi antenna is probably the most suitable to be used as a reference parameter by which all antennas can be compared. This geometrical parameter of antenna directly determines gain of antenna as one of the most important factors.

I decided to sort all analyzed antennas according to their boom length in wavelengths as an ascending series. This gives me systemized set of antenna results and thus better insight in the antenna performances by comparing them to the antenna neighbours and also to the other antennas in series.

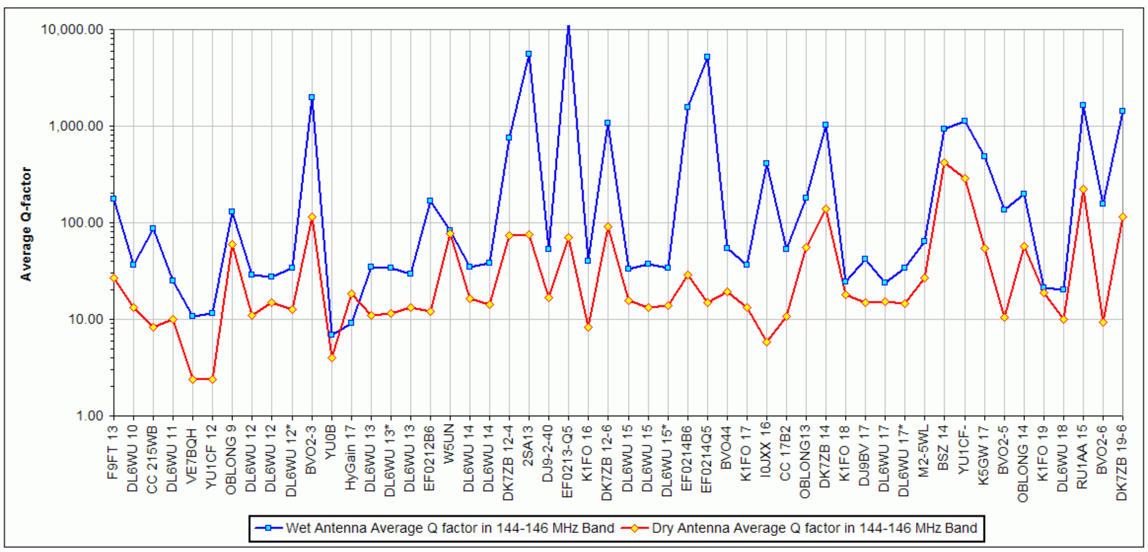
The **gain** of optimally designed Yagi antennas should increase about 2.3 dB for every boom length doubling according to DL6WU works from almost 30 years ago. As we can see from diagram for the antennas between DL6WU 11 which has boom length about L=2.5 wl and gain G=14.3 dBi, and DL6WU 18 with L=5.2 wl and G=16.9 dBi, this rule of thumb is quite accurately confirmed. Let’s try to examine this diagram more carefully.

It is easy to see that some dry antennas have gain that is up to 1 dB above the black colored average gain line. If we look at their boom length we can see that they are usually also above the black colored boom length line. Most often this little longer antenna boom explains little higher antenna gain.

There are also few antennas which have little higher gain, usually up to 0.5 dB, which do not have longer boom. It means that their designers derive 0.5 dB higher gain from these antennas than the others did on the same boom length. However, if we look at the blue line which shows the wet antenna gain we can easily conclude that this 0.5 dB of higher gain on the same boom length is dearly paid by the poor antenna behavior under the wet weather conditions.

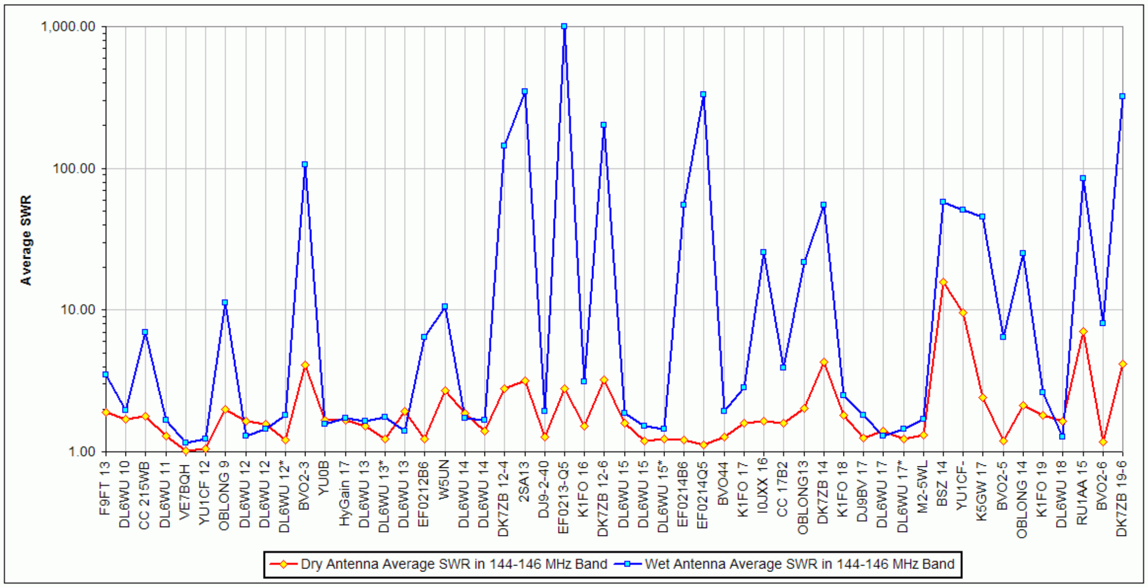
And finally there are really just a few antennas which have so good design which satisfies both demands: to have the highest possible gain, usually very close or little above black average gain line, and that this gain does not drop down under wet antenna conditions! You can easily recognize them where the blue and the red lines touch each other or are very close, and in the same time boom length is not above the average black line.

The **Q factor** of antenna is also another parameter which shows important antenna characteristics [2]. If we look at the diagram of Q factor for dry and wet antennas we can see very good agreement between gain and Q factor values for dry and wet antennas.



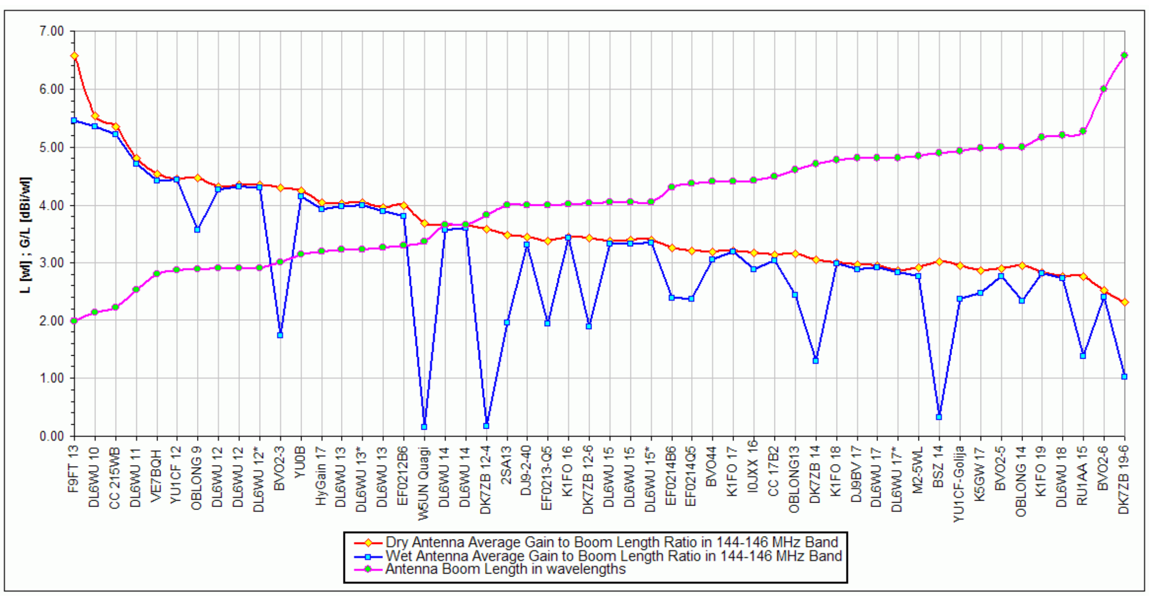
Average Q-factor of dry and wet Yagi antennas of various experimenters

Each time when the wet antenna gain decreased, the Q factor simultaneously went up. Such antenna, beside its lower gain, usually changes its input impedance, changes the radiation characteristics and becomes very sensitive to the influences of its environment. Good antennas can be easily identified by very small Q-factor values both for dry (red line) and wet (blue line) antennas.



Average SWR of dry and wet Yagi antennas of various experimenters

The **SWR** of antenna also follows closely the antenna gain drop and the Q factor rise as we can see on diagram of SWR for dry and wet antennas. The antenna SWR rises when the Q factor rises and the gain drops down due to moist. The higher antenna SWR means the higher cable losses and the lower total efficiency of the overall antenna system.
The good performers have both dry and wet antenna SWR very low.



Boom length and average gain to boom length ratio
of dry and wet Yagi antennas of various experimenters

The antenna average gain per boom (wave) length, G/L is another interesting performance value comparison of the simulated antennas. By dividing antenna gain by boom length we get value which shows us how many dBi of gain particular antenna produces per wavelength of its boom length.

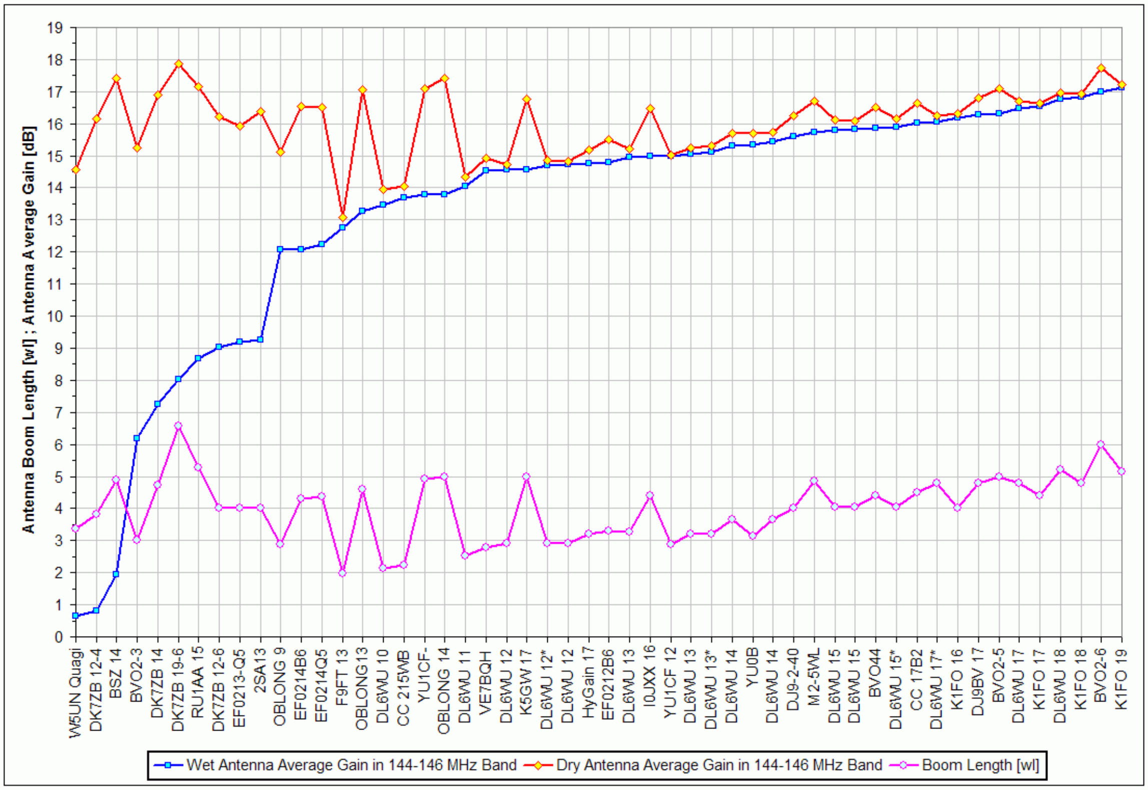
By plotting boom length in wavelengths on the same diagram with G/L plot we can see that for the longer antennas we can get less gain per boom wavelength then for the shorter ones. If we take the same antenna boom length range between 2.5 and 5.2 wavelengths we can see that the antenna gain per boom wavelength decreases about 2 dB for boom length doubling.

It is quite important to have this in mind especially when one wants to build large antenna system consisted of many antennas. In that case one have to decide whether it is better to put more short antennas or fewer long antennas in a system to achieve desired system gain.

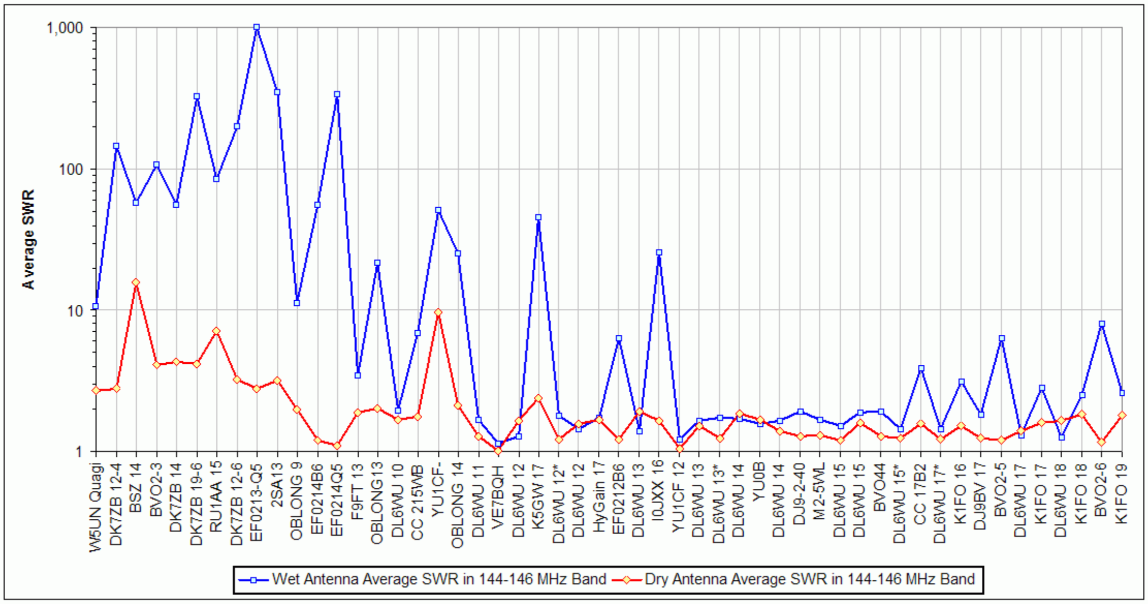
On this diagram good antennas show very close values for dry and wet working conditions.

For easier recognition of good antenna performers, especially under wet weather conditions, I sorted all antennas as wet antenna gain ascending series, which changed their order from previous one, and generated the diagrams of wet and dry antenna gain and SWR.

These diagrams, with such changed antenna designs order perhaps give more clear difference between antennas in different working conditions.
Again, the best performers are those with very close or touching red and blue lines.



Boom length and average gain of wet and dry Yagi antennas of various experimenters sorted according to wet antenna gain increase



Average SWR of wet and dry Yagi antennas of various experimenters sorted according to wet antenna gain increase

Conclusion

In this paper I presented the simulations results of over 50 different antennas for the 2m band. There are some antennas from the same designer but with some small variation, usually with different elements diameter, or calculated with different program such as DL6WU*. Antennas are marked with the * sign to show that DL6WU antennas are calculated with program written by G3SEK.

All antennas are simulated under the absolutely identical dry and wet working conditions. The results are averaged over 144-146 MHz frequency band.

Looking at the presented diagrams we have to conclude, not without bitterness, that almost all our efforts on improving Yagi antennas for nearly last 30 years did not give any significant improvement in antenna design in spite that we were using very powerful computers and programs for optimizations to accomplish this task.

For such a long time, great number of designers, with powerful computers and so many new antenna designs didn't succeeded in improving Yagi antenna gain for more than the marginal value of 0.5 dB! And even more, this small improvement very often has to be paid very expensively by sacrificing some other important performances of the Yagi antenna.

What does it mean? Does it mean that the possible theoretical maximum of Yagi antenna performances has already been reached 30 years ago?

If it is so, and many facts show that it is, isn't it the final time to stop unfruitful endless "improving" of existing Yagi antennas and flood of "new" and "best" Yagi antenna designs which most often can not even reach, let alone exceed performances of "old" ones, and instead try to really invent something radically new and better?

Science progress is in new, fresh ideas, not in endless reiterating old existing answers!

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References

1. Dragoslav Dobričić, YU1AW, **Performances of Wet Yagi Antennas**, *antenneX*, August 2008, issue No. 136.
2. Dragoslav Dobričić, YU1AW, **Yagi Antenna Q factor**, *antenneX*, July 2008, issue No. 135.
3. **Insulated Wires - The NEC-2 Way**, L.B. Cebik, Antenna Modeling, http://www.antennex.com/library/w4rnl/col0105/amod83.html

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.

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