Boom Radius Influence on Yagi Antennas

Dragoslav Dobričić, YU1AW (Serbia)
dragan@antennex.com

Introduction

Six different Yagi antennas for the 2-meter band which have the same boom length and very similar gain but different sensitivity to environmental impacts due to their different average Q factors are used to investigate how a boom influences on Yagi antenna performances.

They all have the same boom length of 4 wavelengths, gain of around 16-16.5 dBi, but when dry or wet, the average antenna Q factors differ by more than 10 times! **[2]** Different Yagi antenna designs show different sensitivity to environmental impacts and it can be expected that an antenna boom, as an intruder, can show different effects on different antenna designs as well. This series of simulations were conducted to check these expectations.

On the same boom length, these six antennas have a different number of elements ranging between 12 and 16. All six antennas were simulated keeping all the other conditions the same and with highest reasonable accuracy.

For this task antenna simulation software based on FIT method is used instead of usual MoM based software which has been found inadequate due to a few unacceptable program limitations **[1].**

Antenna parameters on which boom influence was expected and monitored were:

1. Antenna input return loss (S11) given in dB
2. Broadband directivity given in dB over isotropic radiator
3. Antenna directivity pattern in E and H planes

Input return loss is normalized to 50 ohms impedance for all simulated antennas except for DK7ZB-12-6 which is normalized to 28 ohms impedance according to antenna impedance claimed by its author.

Broadband directivity and input return loss were monitored within frequency band 142-148 MHz that is wider than amateur band in order to enable better insight to boom influence on Yagi antenna performances.

Yagi antennas were simulated without boom and later with a conductive round tube boom added. The boom is placed below the elements so that distance between the boom's top-most surface and elements axis is kept at a constant value of 7 mm. Then boom radius (**br**) was changed from 10 to 50 mm. It represented a simulation of a Yagi antenna with elements insulated from a boom and mounted on booms with different diameters

(20-100 mm) with the aid of plastic insulators with very low dielectric permittivity and constant height of elements above the boom.

Simulation results

For the better comparison of obtained data, diagrams were arranged in groups, not by antenna type, but by monitored antenna characteristic. In this way one can more easily compare results of different antennas and boom impact on the particular antenna characteristic.

On the diagrams presented we can see that curves of antenna input return loss shift on higher frequency simultaneously with enlargement of the boom diameter. This is a result of the well known effect predicted by theoretical calculations and verified by practical measurements, i.e., that the presence of a thick conductive boom near the elements tends to shorten effective length of the elements and thus shifts performances of the antenna to a higher frequency.

Antenna resonance and other characteristics also shift to a higher frequency. The boom influences on an antenna produce frequency shifts which are just opposite of those that the moist on antenna elements does. Conductive boom presence and its effects partly “compensate” the moist effects on antenna elements! That is the main reason why many wet antennas work better than MoM based programs predict. MoM based programs like NEC-2 or NEC-4 do not “see” all the induced boom currents and thus can not calculate “compensating” boom effects on dry and wet antenna performances.

Paradoxically, it seems that antenna performances calculated by NEC program without considering any boom effects and built on boom of nonconductive material suffers more due to moist influence than the performances of the same antenna built on a conductive boom. Such is due to lack of a conductive boom “compensating” effects on wet antenna performances.

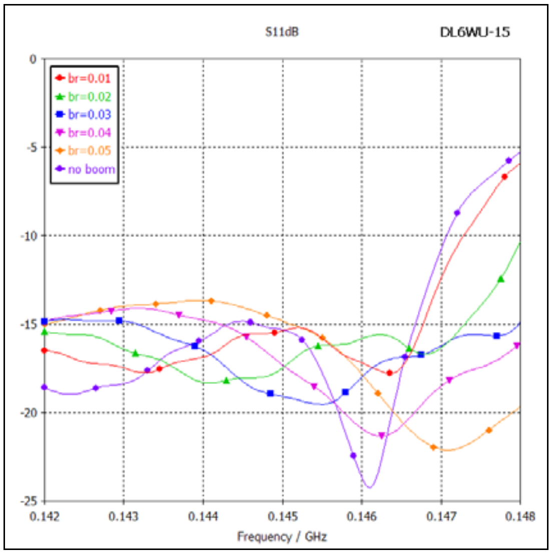
Input Return Loss

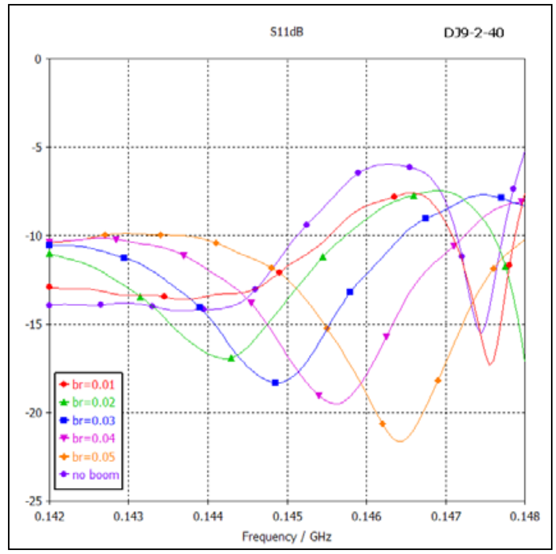
From the presented diagrams of input return loss, we can see considerable shift toward higher frequencies when boom radius increases. Frequency shift is 0.5 - 1 MHz for every 10 mm of boom radius increase. Considering 2 m amateur band width of 2 MHz in Europe, it is up to 50%!

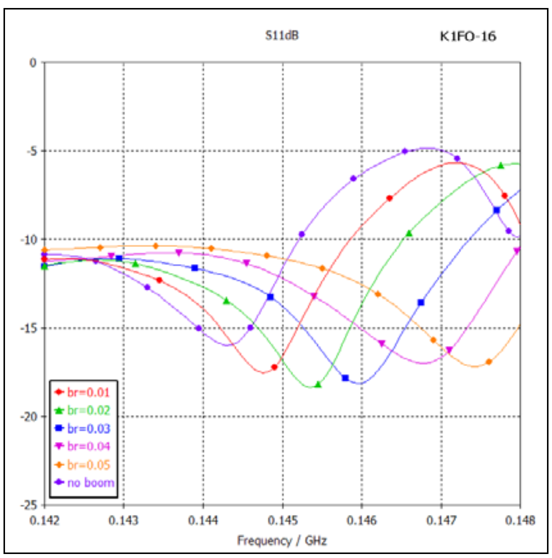
Antennas with high and low Q factors both have similar absolute value of the “best matching” frequency shift, but antennas with lower average Q factors usually give considerable wider matching band due to its larger working bandwidth and good behavior on the higher part of band.

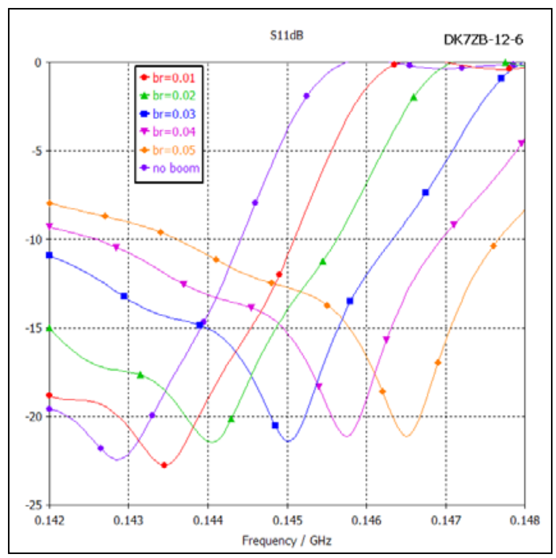
For some antennas, usually those with low average Q factors, conductive boom effects are “constructive” in a way that they, beside frequency shift, also broaden antenna working bandwidth. At the same time for other antennas with the presence of a conductive boom produces only frequency shift of matching bandwidth without significant broadening effects.

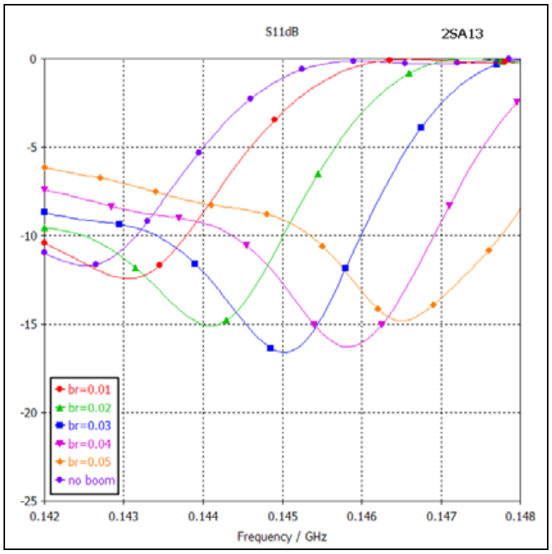
Variation of input return loss and maximum difference within frequency for DX band 144-145 and the whole European band 144-146 MHz are given in Table 1. From results in Table 1 it is obvious that antennas with lower average Q factors have less variation and difference of input return loss due to increase boom radius in chosen frequency bands.











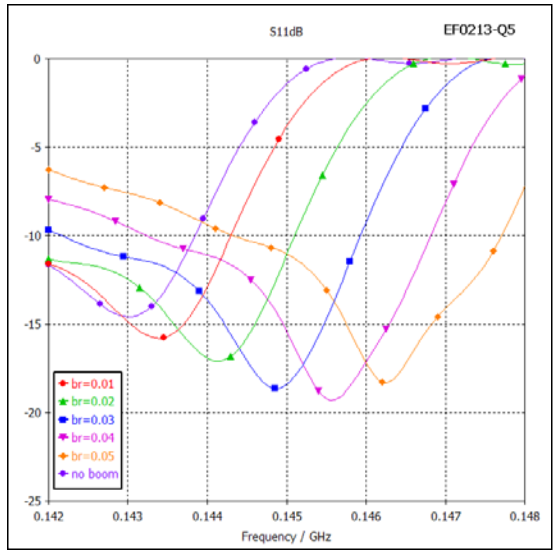


Table 1

Antenna type	Dry/Wet antenna average Q factor	Return Loss variation 144-145 MHz [dB]	Return Loss difference 144-145 MHz [dB]	Return Loss variation 144-146 MHz [dB]	Return Loss difference 144-146 MHz [dB]
DL6WU-15	13.8 / 16.3	-13.7 – -19.1	5.4	-13.7 – -23.5	9.8
DJ9BV-2-40	16.9 / 20.2	-10.2 – -18.3	8.1	-6. 2 – -19.5	13.3
K1FO-16	8.3 /12.7	-10.5 – -17.5	7.0	-6.3 – -18.3	12
DK7ZB-12-6	91.7 / 252.6	-3.9 – -21.5	17.6	0.0 – -21.5	21.5
2SA13	75.1 /224.7	-1.0 – -16.6	15.6	-0.1 – -16.6	16.5
EF0213-Q5	70.4 / 291.3	-1.4 – -18.6	17.2	0.0 – -19.3	19.3

Broadband directivity

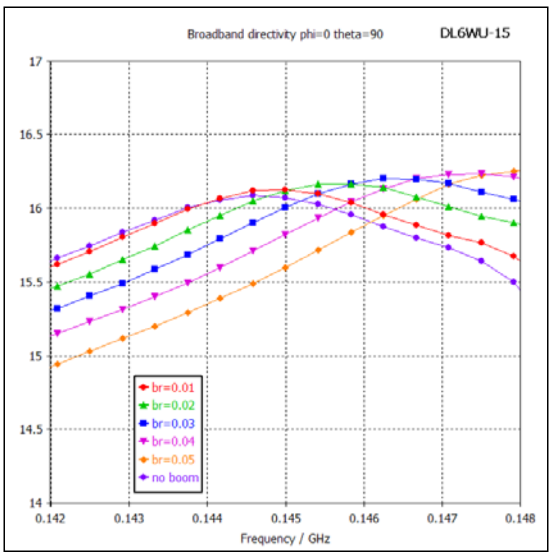
As expected, antenna broadband directivity curves also shift toward higher frequencies due to a conductive boom influence. For all antennas it is noticeable that certain directivity curve broadening is due to conductive boom influence. Both effects can produce significant variation of antenna directivity within amateur band width.

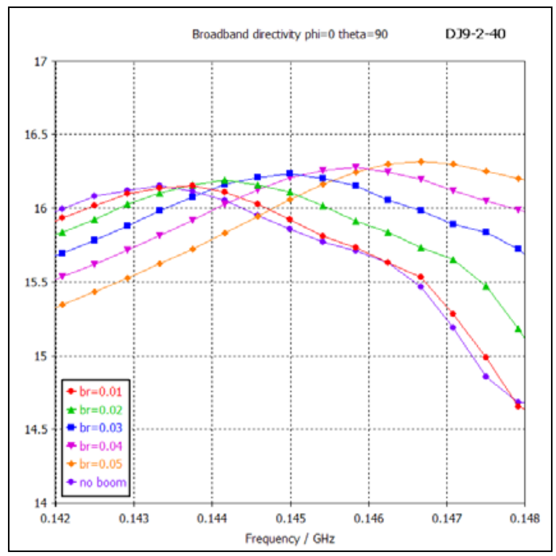
This directivity variation is given in Table 2 for the whole (European) band 144-146 MHz and for DX part 144-145 MHz. Besides antenna directivity variation due to different conductive boom radius impact within these two frequency bands, maximum directivity differences that can be expected within bands are also given.

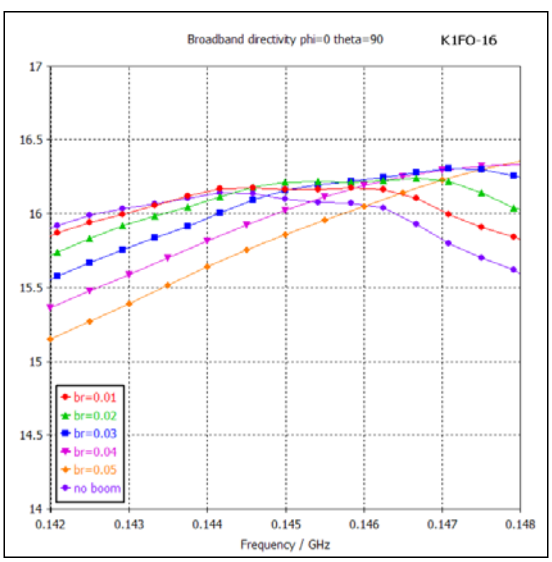
Antennas with high average Q factor show higher value of directivity variation as a result of higher sensibility to boom influence and narrower working bandwidth.

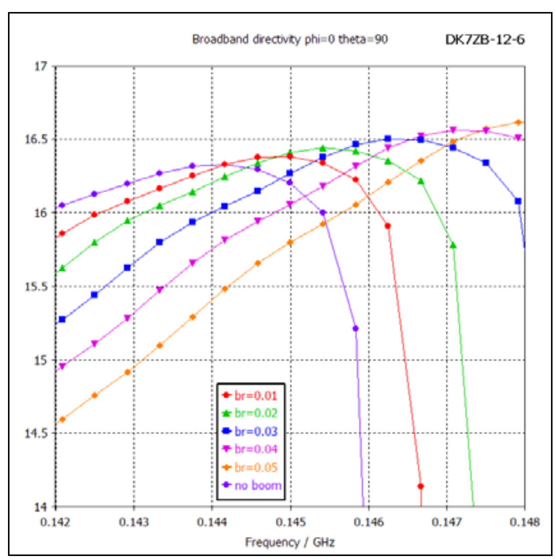
Table 2

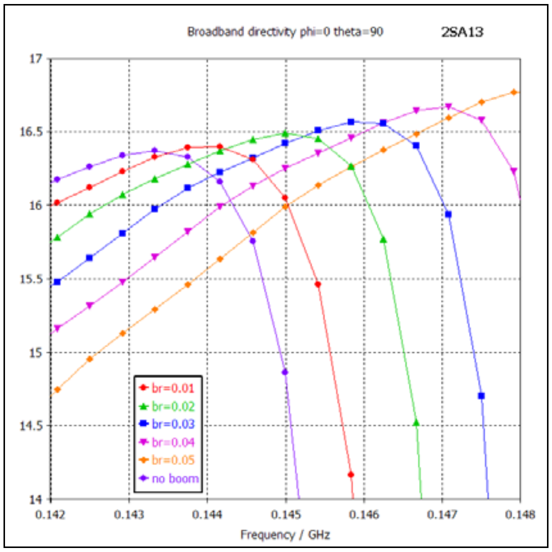
Antenna type	Dry/Wet antenna average Q factor	Directivity variation 144-145 MHz [dB]	Directivity difference 144-145 MHz [dB]	Directivity variation 144-146 MHz [dB]	Directivity difference 144-146 MHz [dB]
DL6WU-15	13.8 / 16.3	15.3 − 16.1	0.8	15.3 − 16.2	0.9
DJ9BV-2-40	16.9 / 20.2	15.8 − 16.2	0.4	15.7 − 16.3	0.6
K1FO-16	8.3 /12.7	15.6 − 16.2	0.6	15.6 − 16.2	0.6
DK7ZB-12-6	91.7 / 252.6	15.4 − 16.4	1.0	13.1 − 16.5	3.4
2SA13	75.1 /224.7	14.8 − 16.5	1.7	1.4 − 16.5	15.1
EF0213-Q5	70.4 / 291.3	15.1 − 16.2	1.1	4.7 − 16.3	11.6

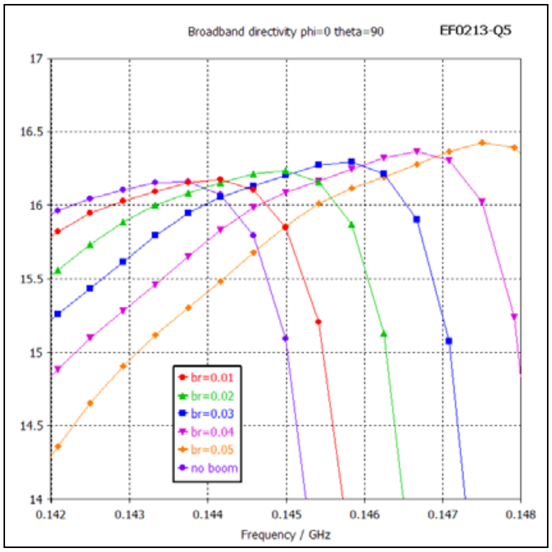












Antenna pattern

All antenna patterns were taken on the144.5 MHz frequency. This frequency is chosen because the antennas with high average Q factors usually have considerable distorted radiation patterns on higher frequencies. They are usually computer optimized only for work at the lower portion of the 2 m band and thus they are conditioned for this choice of frequency.

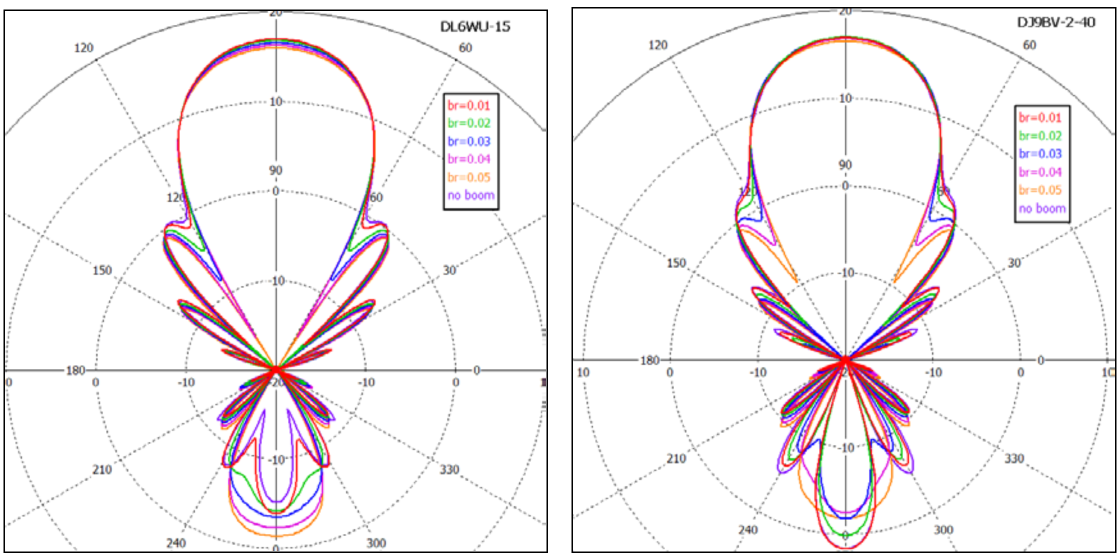
On the presented polar plots of antenna directivity in E and H plane, it is visible that largest impact of a conductive boom is on the angular position and magnitude of the first side lobes and the back lobe.

Antennas with low average Q factors show a more stable angular position and less magnitude variation of side lobes in both E and H planes. Variation of back lobe magnitude with a change of boom radius is also lower for antennas with lower average Q factors.

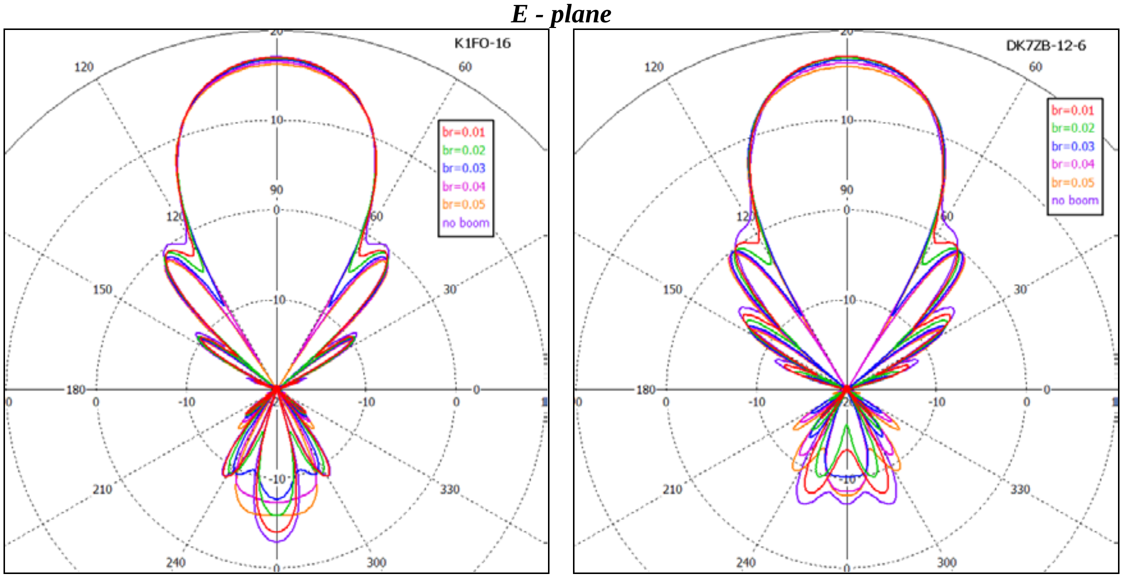
Due to permanent changing angular position of the first pair of side lobes, it was difficult to make precise quantitative comparisons and present them in an adequate table. Directivity pattern in the Cartesian coordinate system gives me better results and I used it for evaluating the data in Table 3. Back lobe variation and thus antenna F/B ratio variation due to conductive boom influence is also given in Table 3.

Table 3

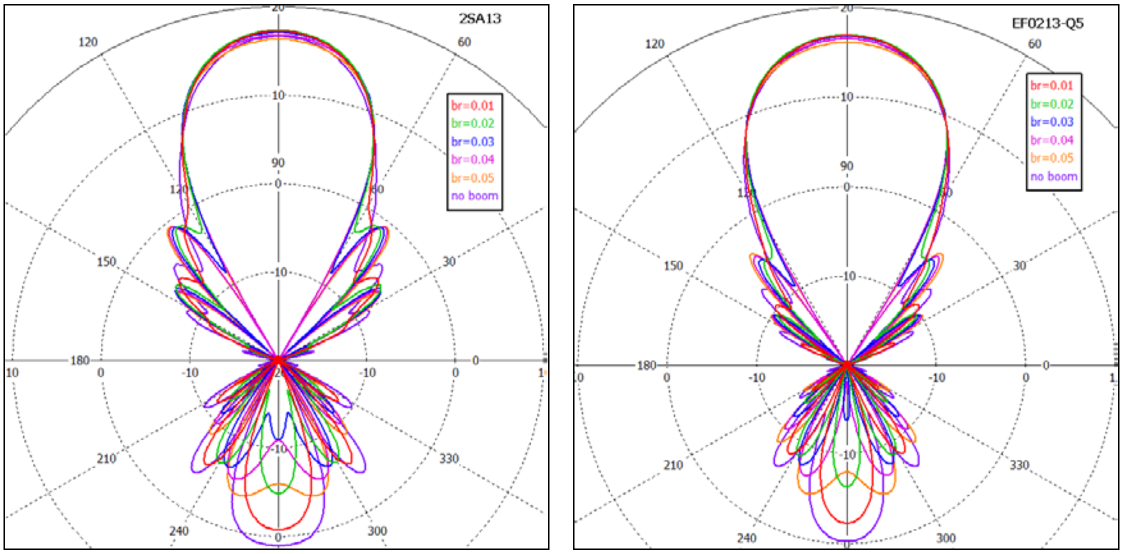
Antenna type	Dry/Wet antenna average Q factor	E plane first side lobe magnitude difference [dB]	H plane first side lobe magnitude difference [dB]	E plane first side lobe angular difference [Deg.]	H plane first side lobe angular difference [Deg.]	Back lobe magnitude difference [dB]
DL6WU-15	13.8 / 16.3	1	0.2	4	3	3.9
DJ9BV-2-40	16.9 / 20.2	3	2	5	7	4
K1FO-16	8.3 /12.7	1.5	0.6	3.5	3	4.7
DK7ZB-12-6	91.7 / 252.6	1	1	6	7	9
2SA13	75.1 /224.7	3.6	2.2	11	11	12
EF0213-Q5	70.4 / 291.3	6	4.2	12	13	12.8



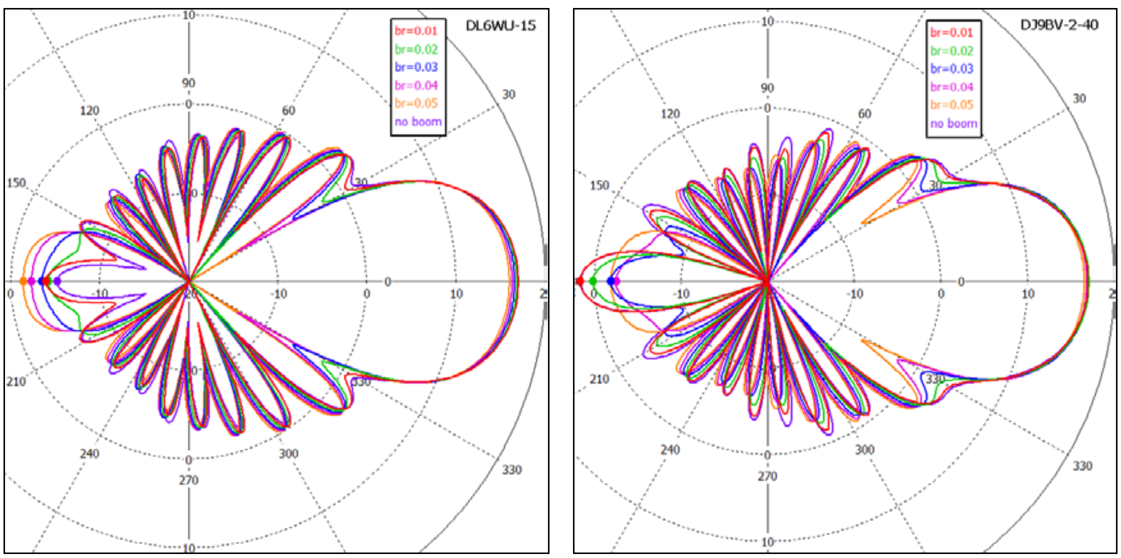
E - plane



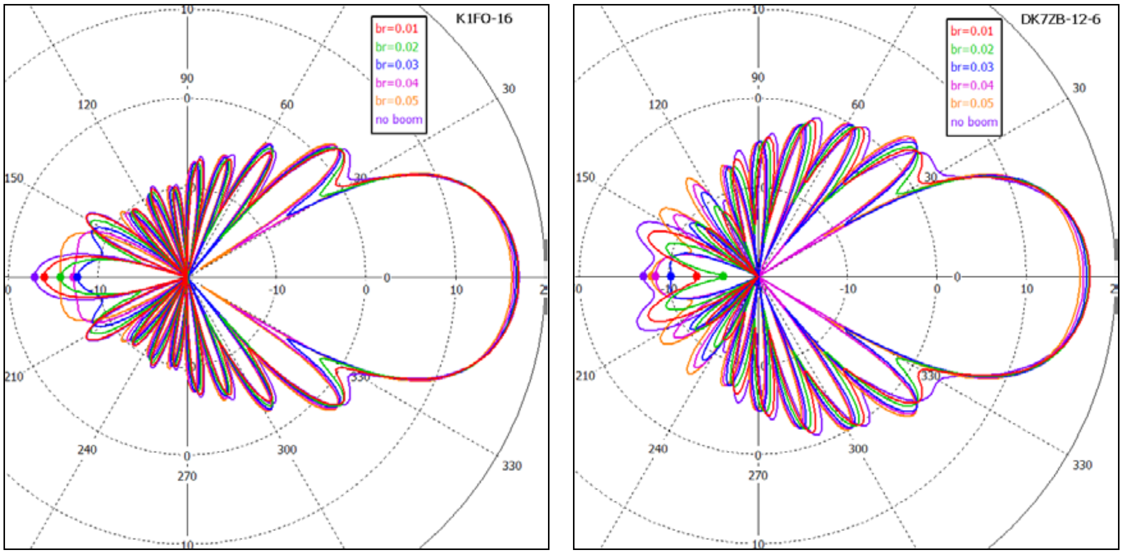
E – plane



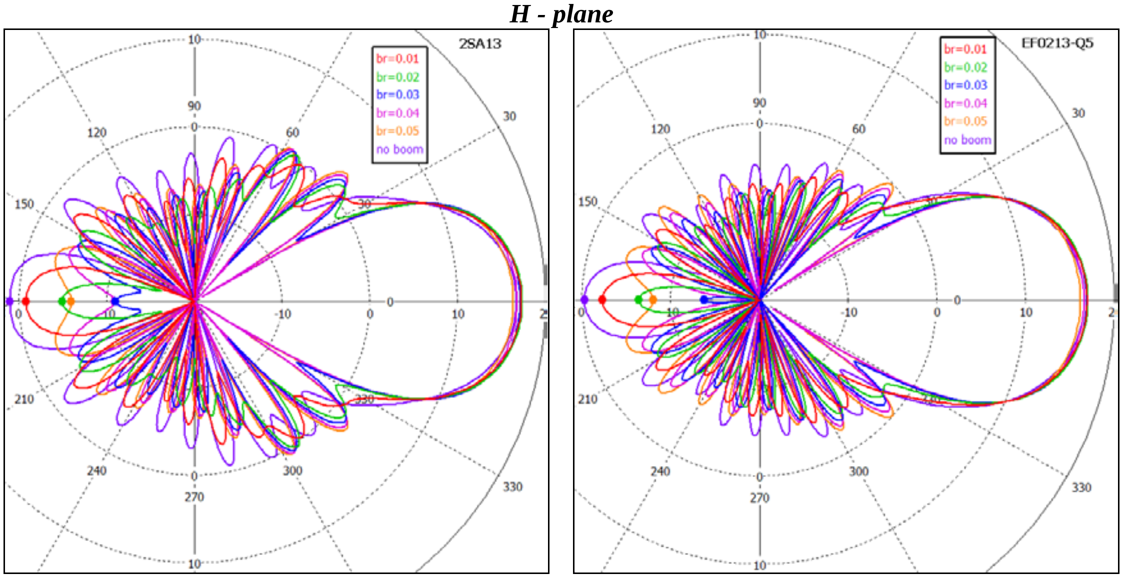
E – plane



H - plane



H - plane



H - plane

Conclusion

In this paper I presented simulations and analyzes of conductive boom radius influence on Yagi antenna performance. Boom effects on antenna input return loss, broadband directivity and radiation pattern for different antennas were compared and correlation between antenna average Q factor and these effects are established. It is found that an antenna Q factor is an important parameter which defines antenna susceptibility to boom effects.

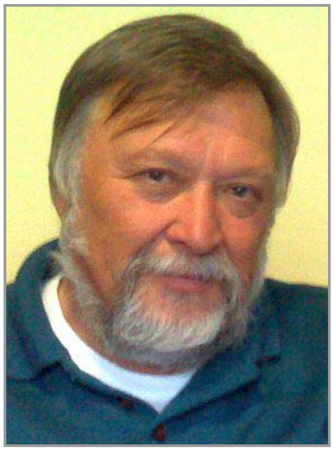
In the next issue we are going to investigate how fixed radius boom on different distances from antenna elements influences on Yagi antenna parameters. **-30-**

References:

1. Dragoslav Dobričić, YU1AW, **Boom Influence on Yagi Antenna**, *antenneX*, May 2009, Issue No. 145.

2. Dragoslav Dobričić, YU1AW, **Yagi Antenna Design Sensitivity in Practice**, *antenneX*, November 2008, Issue No. 139.

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