Yagi Antenna Elements Boom Correction

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Introduction

The boom of Yagi antenna is inevitable part of its construction. Theoretically, Yagi antenna can work fine without a boom. Practically, that is possible only if boom is made of non-conducting material (wood, fiberglass, etc.). A conducting boom is not intended radiating part of antenna but only an inevitable part of its support construction.

The Yagi antenna can be built in few ways. It can be built so that elements are insulated and separated by some safe distance from any conducting boom. Another way is to build antenna so that elements pass through boom. This method can be done in two different ways: first, elements electrically bonded to boom, and second, elements electrically insulated from boom. All of these elements mounting methods have their advantages and disadvantages and different boom influence to antenna elements.

So far, in several previous articles **[1, 2, 3]**, we have investigated how boom radius and its distance from antenna elements influences performance of six different 2 m Yagi antennas which are very similar in all characteristics except in Q factor values **[4, 5]**. In these articles we show how this unnecessary but inevitable "intruder" influences Yagi antenna performances when elements are insulated and separated by various distance from conducting boom.

How did boom influence on the elements that are passing through a boom and they are not insulated from it? This is the question which we will try to answer with this investigation which results are presented in this article.

The presence of a conductive boom and its diameter value has an influence on a Yagi antenna and changes both the antenna radiation pattern and input impedance. From the theoretical calculations and practical measurements it is known that the presence of a thick conductive boom near the elements tends to shorten effective length of the elements and thus shifts performance of the antenna to a higher frequency. On the diagrams presented in our past articles we could see that curves of both input resistance and reactance shift on higher frequency simultaneously with enlargement of the boom diameter. As a result of this, antenna resonance and curves of antenna input return loss also shift to a higher frequency. As expected, broadband directivity curves also shift toward higher frequencies.

Different Yagi antenna designs show different sensitivity to environmental impacts and it is expected that an antenna boom, as an intruder, can show different effects on different antenna designs as well.

In this investigation we will examine how metal boom influences antenna performance when not insulated elements are passing through it.
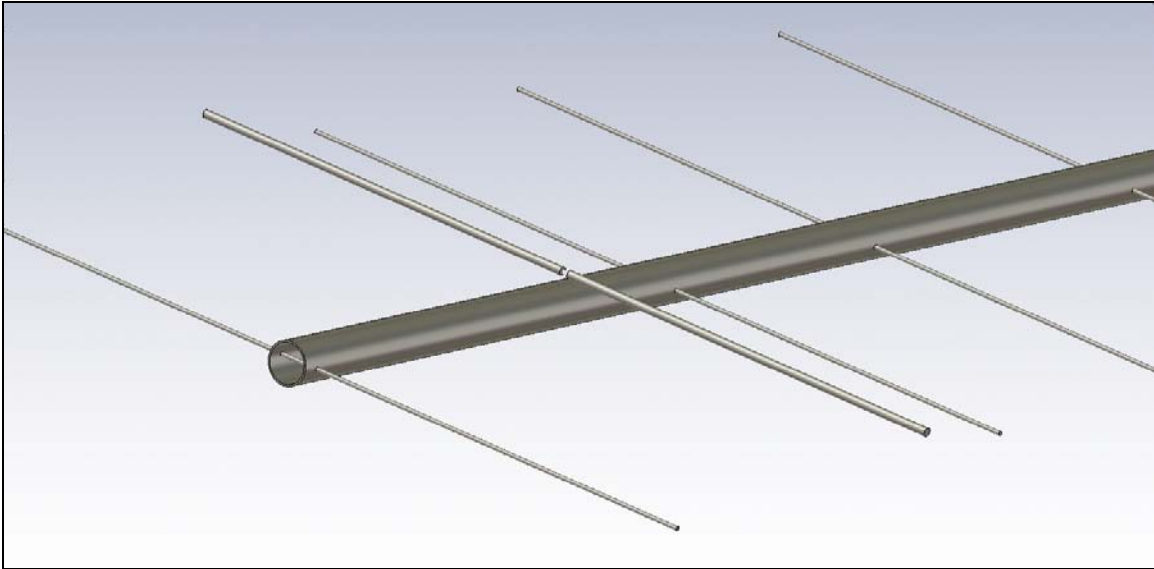
Fig.1 Simulation model of Yagi antenna with not insulated elements passing through metal boom and elevated driven element

Boom correction
In the case of the performance frequency shift due to boom influence it is necessary to compensate it for the length of elements to maintain antenna performances on the desired intended frequency.

Mounting method, boom and elements diameter and distance between boom and elements determine magnitude of boom's impact and value of the necessary elements length correction.

As we already mentioned in one of our past articles, length correction for elements mounted above the boom is proportional to the boom and the element diameters and distance between elements and boom. A general rule of thumb is that for 144 MHz band elements mounted just above the boom surface but electrically insulated from the boom, the correction is about 25% of the boom diameter.

For elements that are mounted higher above boom surface, elements length correction decreases. And at about half of the boom diameter height correction is not necessary because of negligible influence of the boom to the elements' effective length. Unfortunately, in our past investigations it is shown that this is not the truth. Results of conducted simulations show that boom influence is much more long-range than this rule of thumb suggests. It is also found that the maximum distance of 300 mm between boom axis and elements axis, that is about 0.15 wavelengths at 2m band, is not wide enough to produce irrelevant effects on antenna directivity and radiation pattern **[1]**.

For elements passing through the boom and electrically bonded to it, a correction is about 25-45% depending on boom diameter. For elements passing through the boom but insulated from it, a correction is 15-25 % of boom diameter — for usual boom diameters (20-50 mm). Higher correction percentage is for booms with larger diameter which show

a more severe boom influence on the antenna. On higher frequencies, the correction percentage is higher. At 432 MHz it is about two times higher than on 144 MHz.

Simulation conditions

All six Yagi antennas that were used in past articles were simulated again under the same conditions. A variable diameter conductive round tube boom was placed exactly at the axis of antenna so that the elements pass right through the center of round tube boom. The boom axis and elements axis are crossing under right angles (Fig. 1).

It represents a Yagi antenna simulation with elements that are not insulated from a boom and mounted so that they are passing through the conductive boom. Simulation conditions were very similar to a practical situation when a single antenna, with conductive round tube boom and not insulated elements that are passing through it, is mounted on the top of a very tall and slim pole. However, the pole itself is not a part of simulation model.

Elements length has been changed to compensate boom effects. This lengthens of elements known as *boom correction* was varied from 0 to 20 mm. Correction was applied on all elements except driven dipole because it is not passing through boom. Driven dipole element axis is elevated above boom's top most surfaces for about one boom radius. During simulations boom radius was changed from 10 to 25 mm as parameter. The thickness of metal boom tube wall is set to be 2 mm.

Finally, metal boom was removed and antenna without boom and with zero *boom correction* was simulated with the same program's spatial discretization parameters in order to obtain accurate reference results for comparison purposes. These results are designated as "*no boom*" on diagrams.

For this task the antenna simulation software based on FIT method has been used once again. Usual MoM based software has been found inadequate due to some well known and documented program limitations **[3].** Similarly as in the previous articles, boom diameter and boom correction influences have been monitored on the following antenna parameters:
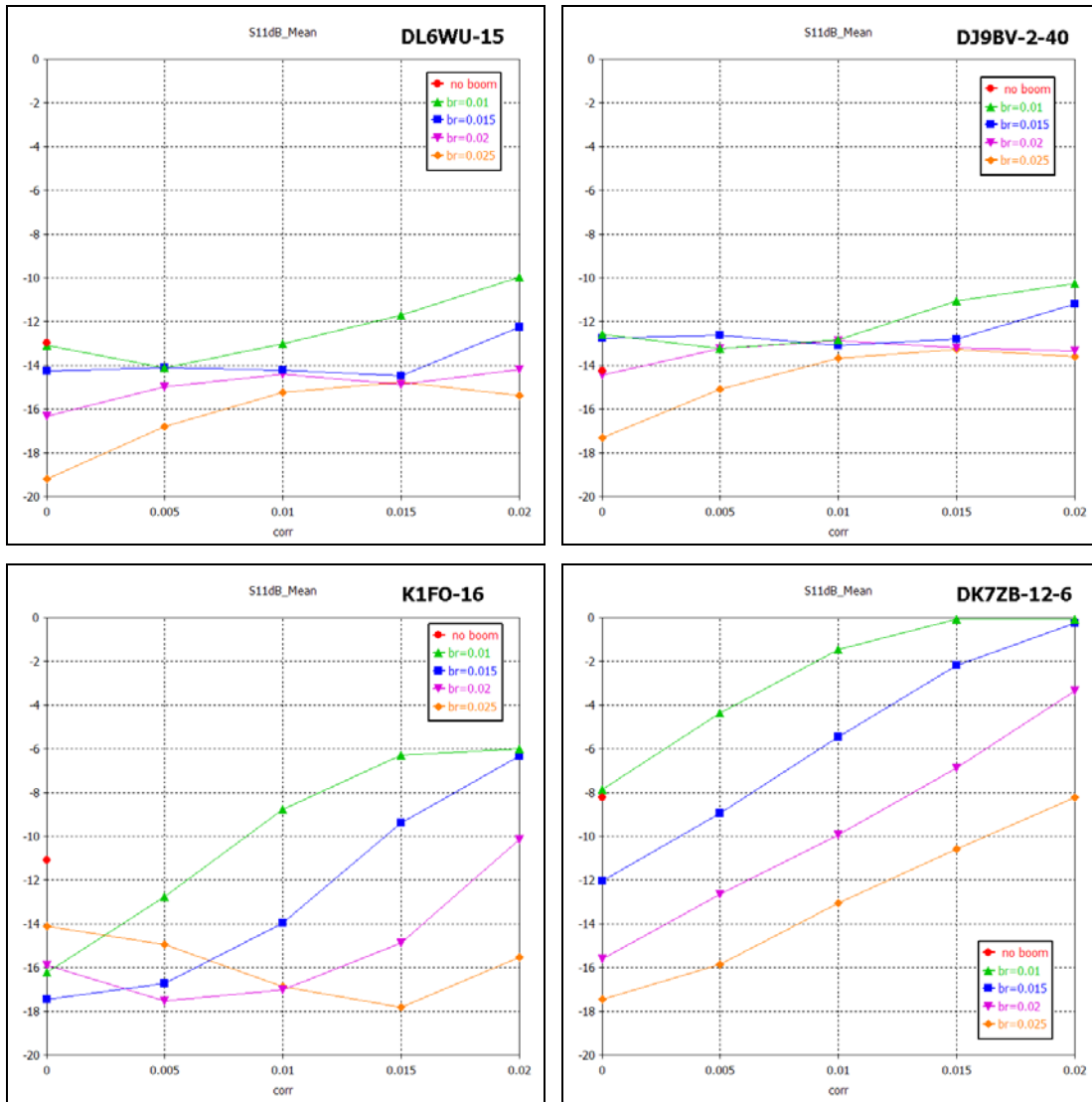
1. Mean value of antenna input return loss (S11) in 144…146 MHz band
2. Mean value of broadband directivity (BD) in 144…146 MHz band
3. Mean value of antenna Q factor in 144…146 MHz band
4. Antenna directivity pattern in E and H planes at frequency 144.5 MHz

This simulation should give an answer to the question what would be the best value of *boom correction* and how it changes with different boom radius and antenna design.

Simulation results

The presence of a thick conductive boom close to the elements tends to shorten the effective length of the elements and thus shifts performances of the antenna to a higher frequency. Maximum of antenna input return loss (minimum SWR), maximum antenna directivity and other characteristics also shift to a higher frequency. Antenna radiation

diagram also changes, in a way that side lobes and back lobe change their magnitude and angular position related to main lobe.
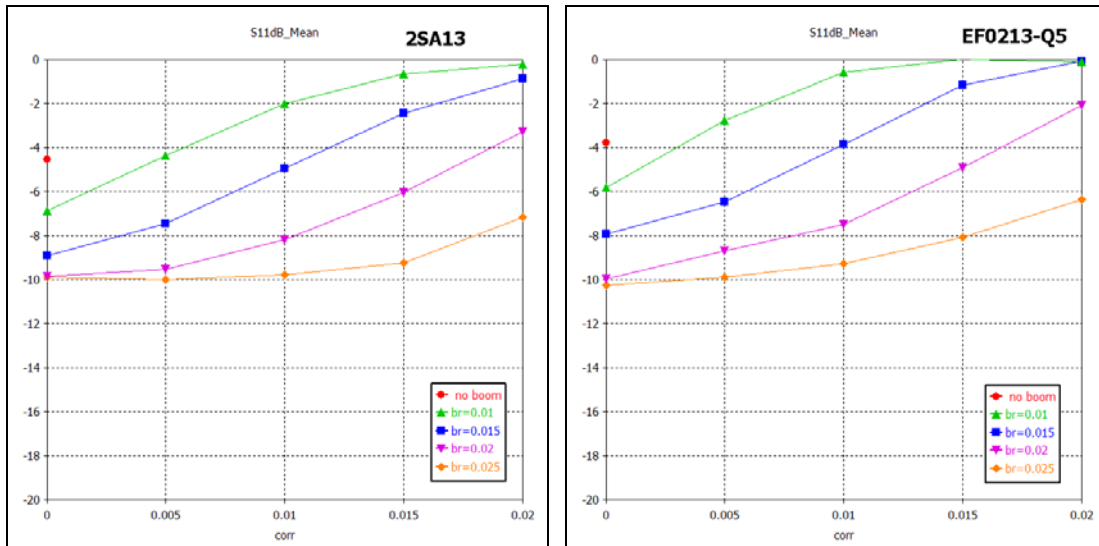
Fig.2 Antenna input return loss mean value in 144…146 MHz band for different boom radius (br) and corrections (corr)

Magnitude of boom influence and thus antenna parameters change depending on boom diameter and it is necessary to apply different *boom corrections* on elements length as compensation for various boom diameters.

However, boom influences, as well as *boom correction* effects, on different antenna performances are usually also different. As a result, we have to decide which antenna parameter (directivity, SWR, working bandwidth, radiation pattern, etc.) is most important for us and choose such *boom correction* value that will best compensate boom effects on this specific parameter. Other antenna parameters will be also compensated but usually in lesser extent and for them some other *boom correction* values might be necessary for optimum compensation.

Input Return Loss
The presented diagrams on Fig. 2 show input return loss mean value dependence of applied *boom correction* for various boom diameters. We can see that only DL6WU and DJ9BV antennas are almost completely independent on applied *boom corrections* and retained good input return loss for all boom diameters and corrections of elements length. This demonstrates their very tolerant design insensitive to severe boom influences and change of antenna element dimensions.

K1FO antenna also demonstrates very good and expectable behavior for boom diameter change and necessary *boom correction*.

Other three antennas, due to their narrow SWR working bandwidth have lower input return loss mean value. Among them DK7ZB antenna has considerably better overall input return loss mean value than other two antennas.

From results on Fig. 2 it is obvious that antennas with lower average Q factors have less variation and difference of input return loss due to variation of boom diameter and applied *boom correction* in chosen frequency band 144…146 MHz.

Also, insensitivity and tolerance of low Q antennas to exact value of *boom correction* for corresponding boom diameter is very noticeable.

High Q antennas generally showed less sensitivity to exact value of *boom correction* only when they were used with larger boom diameter.

Broadband directivity
Antenna broadband directivity mean value curves given on Fig. 3 follow similar trend as input return loss mean value curves on Fig. 2.

K1FO, DJ9BV and DL6WU antennas showed high stability of broadband directivity mean value all over changes of boom diameter and *boom correction* of element lengths. They preserved their high directivity in whole band even when they are compensated with wrong *boom correction* for used boom diameter, or even not compensated at all!
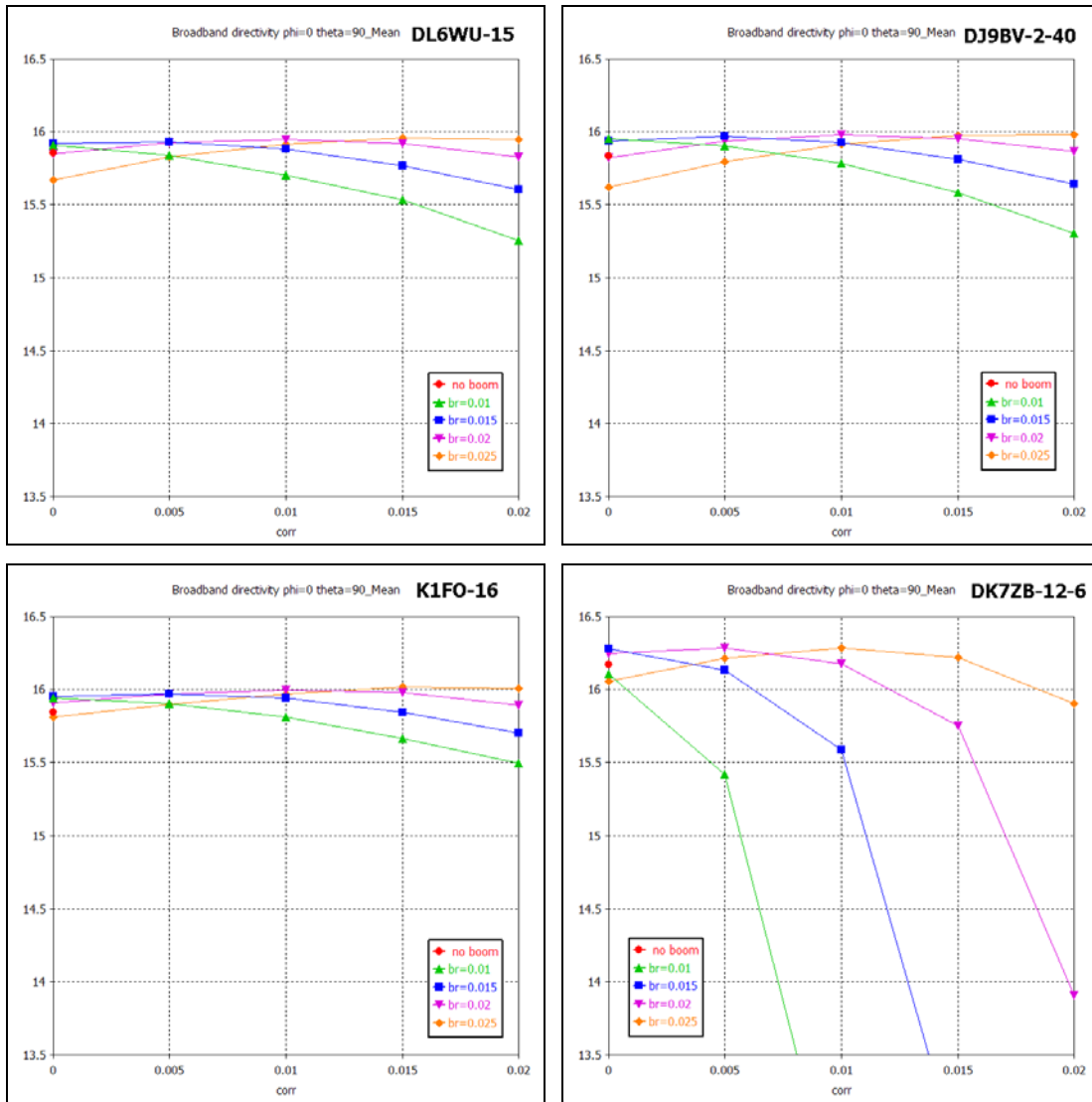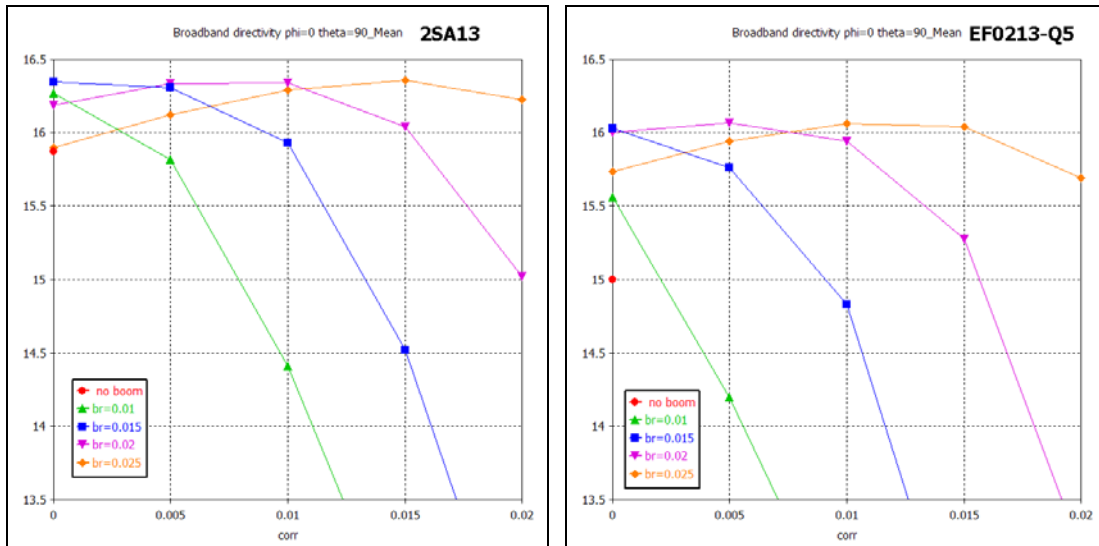
Fig.3 Antenna broadband directivity mean value in 144…146 MHz band for different boom radius (br) and corrections (corr)

2SA13 and DK7ZB antennas showed a little higher directivity (up to 0.5 dB) than other antennas, when they are exactly corrected for optimum directivity performance for used antenna boom diameter. EF0213-Q5 antenna shows similar directivity as three low Q factor antennas but with very high instability of performances for different boom diameters and applied *boom corrections*.

Diagrams on Fig. 3 showed that the antennas with high average Q factor demonstrate higher degree of directivity variation with various *boom corrections* as a result of higher sensibility to boom and elements dimensions and narrower working bandwidth.

Antenna Q factor
Boom influence, together with *boom correction* effects, changes all antenna performances and, among them, changes antenna Q factor. In our earlier investigations we noticed that good antenna design manifest its stability and tolerant behavior by small change of its Q factor under some environmental attack. So, the amount of Q factor change under some influence, along with other parameter changes, becomes the measure of antenna stability and in accordance with this value it was possible to predict how some antenna will probably behave under various environmental influences [4]. This was confirmed many times in almost all past simulations of antennas under various environmental influences [1, 2].

It seems that it is not enough that initially antenna has low Q value under idealized simulated environmental conditions to be considered a good tolerant antenna. It is necessary to check how this antenna changes its initial Q factor in conditions of some severe environmental impact. This difference of Q factor values gives much better insight into antenna quality! Good antennas usually have small difference of initial Q factor value in idealized simulated conditions and Q factor value under some environmental attack [4].

Here again we can see another confirmation of this fact. Antennas that in this investigation showed tolerant behavior preserving good input return loss and stable high directivity mean value under all circumstances, show also very stable and low Q factor mean value — or vice versa.

As it is obvious from diagrams on Fig. 4, DL6WU, DJ9BV and K1FO antennas show stable, flat and low Q factor mean value which is in very good agreement with their input return loss and broadband directivity mean value curves.

It is very interesting that other three antennas have relatively low and flat Q factor only if they are used with very large diameter boom! It seems that very large diameter boom lowers their Q factor and broadens their broadband directivity and working bandwidth. Perhaps this doesn't sound so strange if we know that these antennas are mostly designed without taking boom into consideration because of NEC (MoM) based antenna programs limitations.
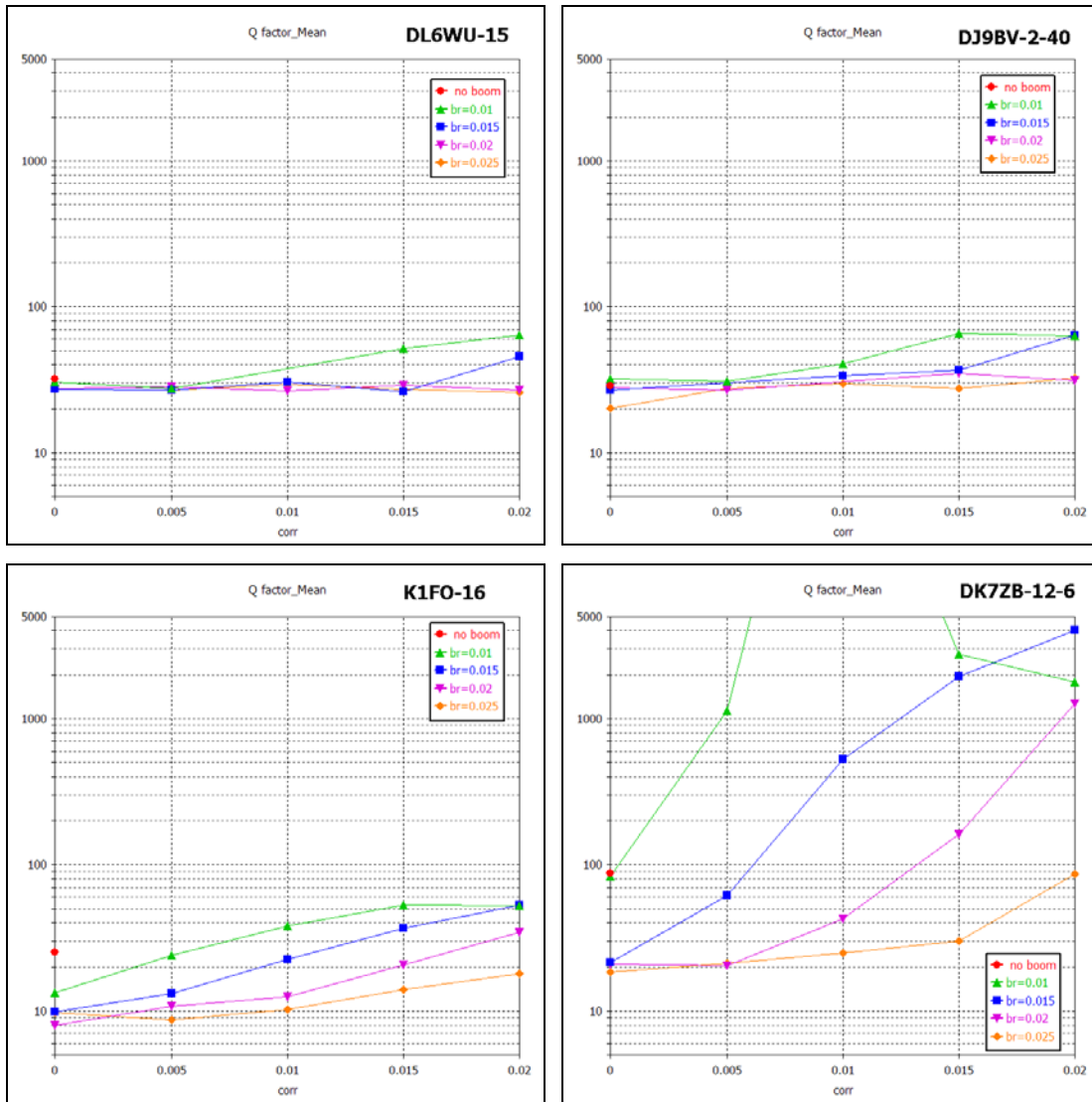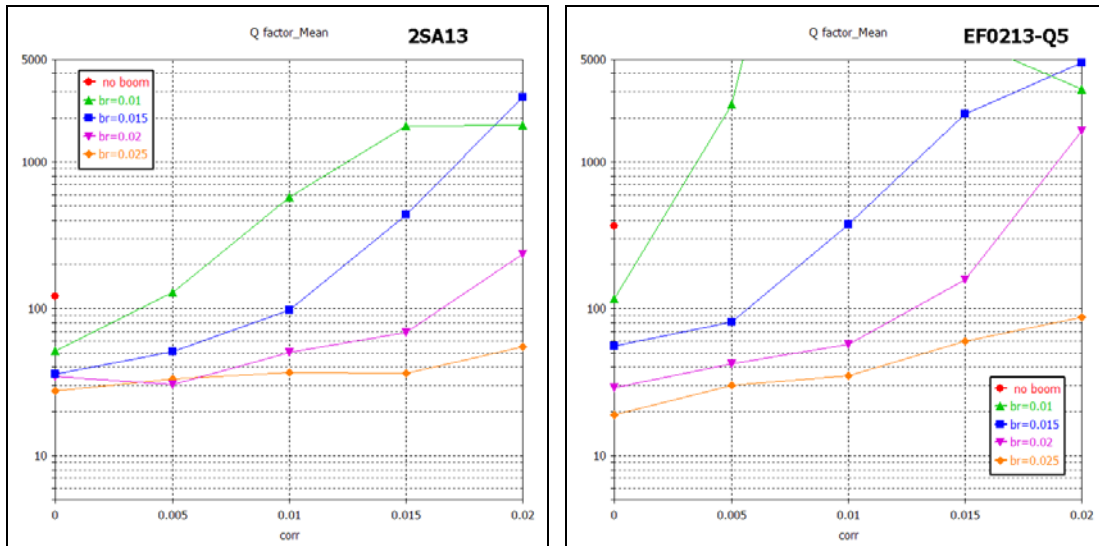
Fig.4 Antenna Q factor mean value in 144…146 MHz band for different boom radius (br) and corrections (corr)

Antenna pattern

All antenna patterns were taken on frequency 144.5 MHz. This frequency is chosen because the antennas with high average Q factors usually have considerably 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.

Because of limited article length it was not possible to publish radiation patterns of all six antennas for all simulated boom radiuses. But as illustration of each particular antenna behavior with various *boom corrections* we decided to publish only patterns for boom radius of 15 mm (30 mm diameter) which is most frequently used for this antenna length.

On the presented polar plots of antenna directivity in E and H plane on Fig. 5 and Fig. 6 it can be seen that largest impact of a conductive boom and various *boom corrections* are on 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 correction* is also lower for antennas with lower average Q factors.

Boom influence compensation

The built antenna behavior depends on the various mechanical solutions that are used for antenna elements mounting. Also, there is very strong parameter dependence on whether antenna is built with conductive or non-conductive boom. Different antenna designs behave differently under the same conditions depending on its Q factor, i.e. sensitivity to environmental influences.

However, with elements mounted not insulated through metal boom we have highest possible interaction between boom and elements. Because of this the highest possible boom impact on the stability of antenna performances is the best visible!

Various radius boom influence optimum compensation by the value of *boom correction* of three important parameters: maximum broadband directivity (BD), minimum Q factor (Q) and maximum input return loss (S11) in whole band of 144…146 MHz for all six antennas are summarized in Table 1. Values designated as "*common*" are those that satisfy optimum compensation all parameters in the same time.
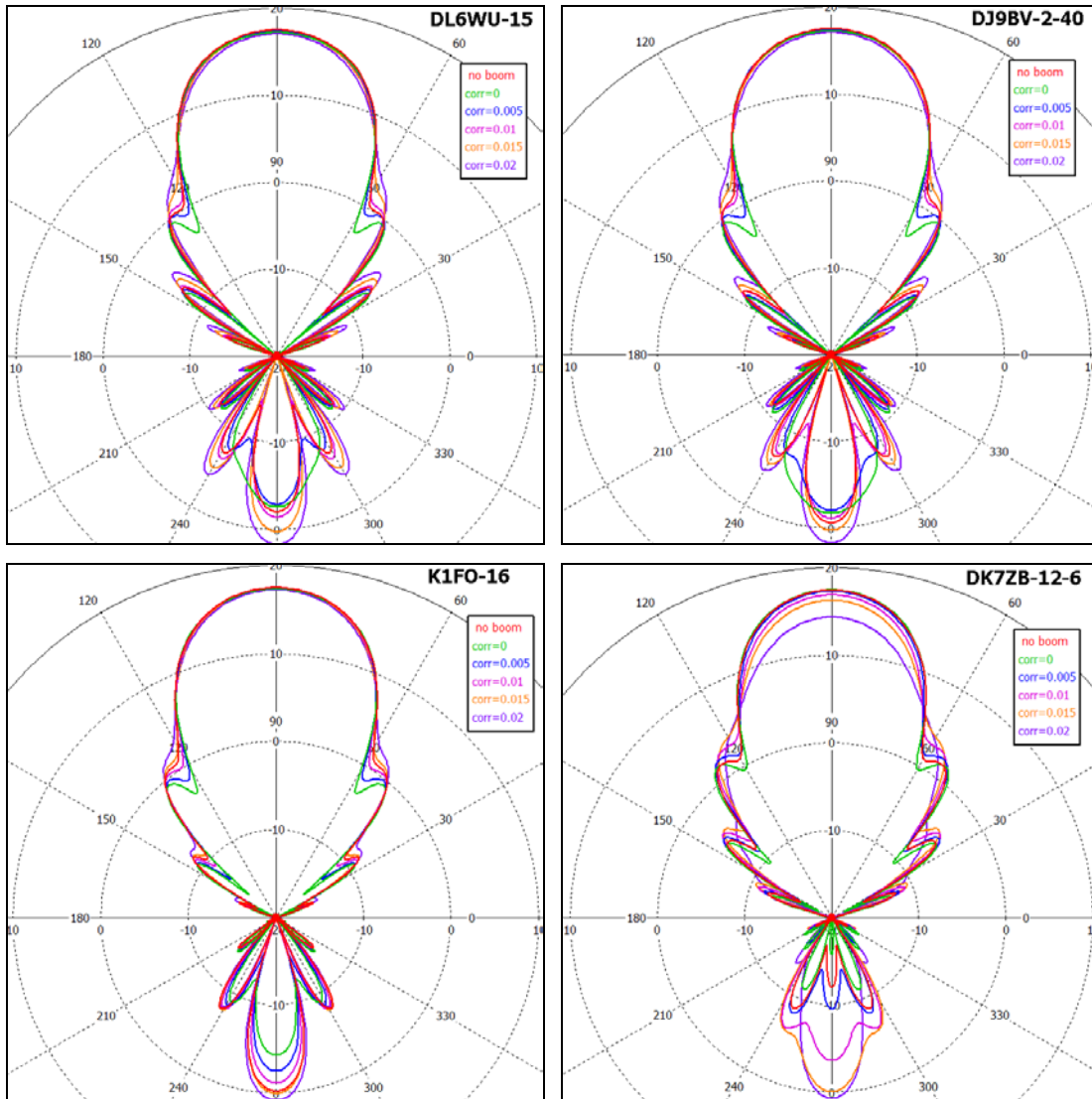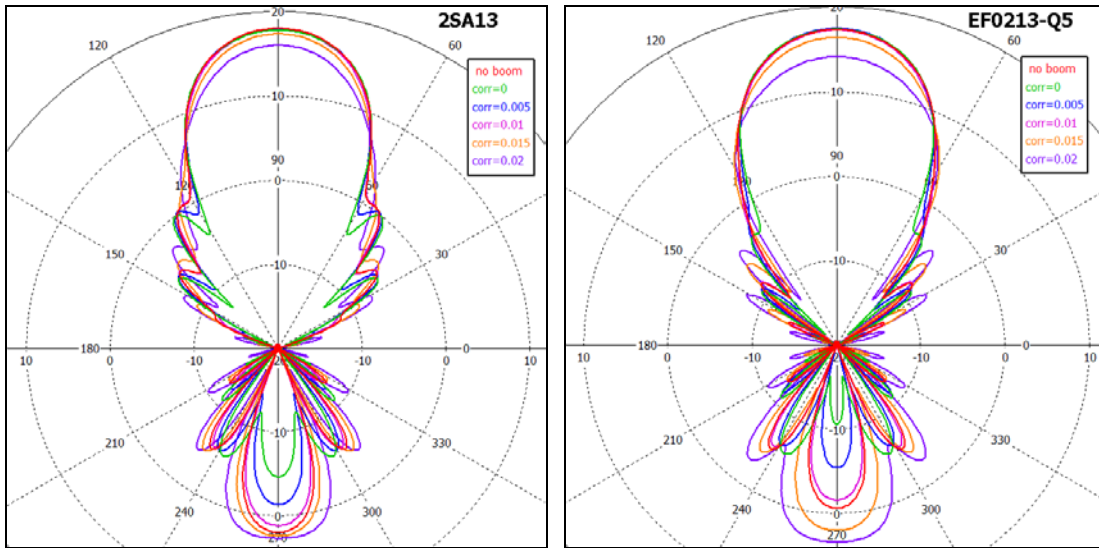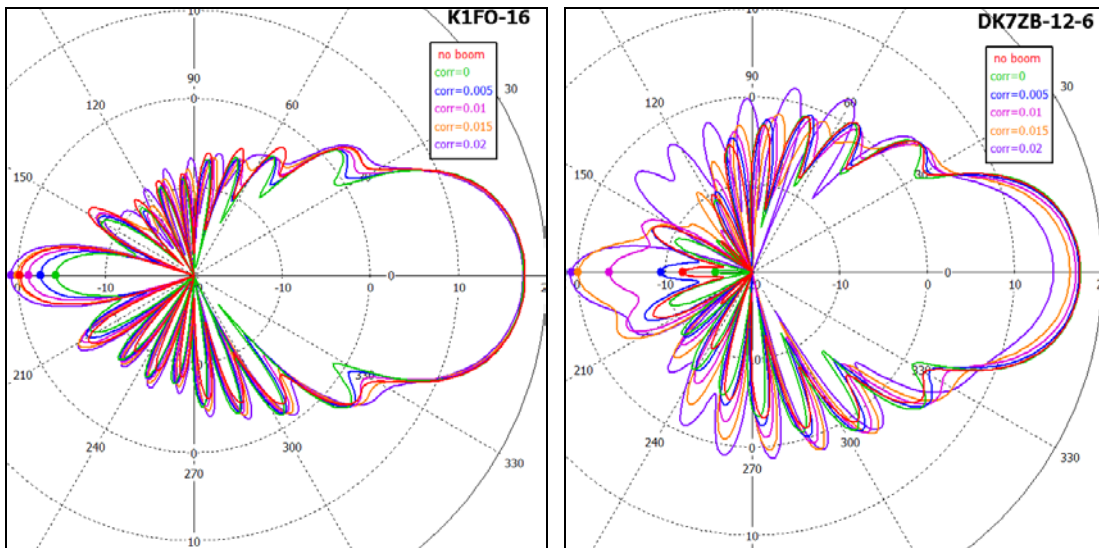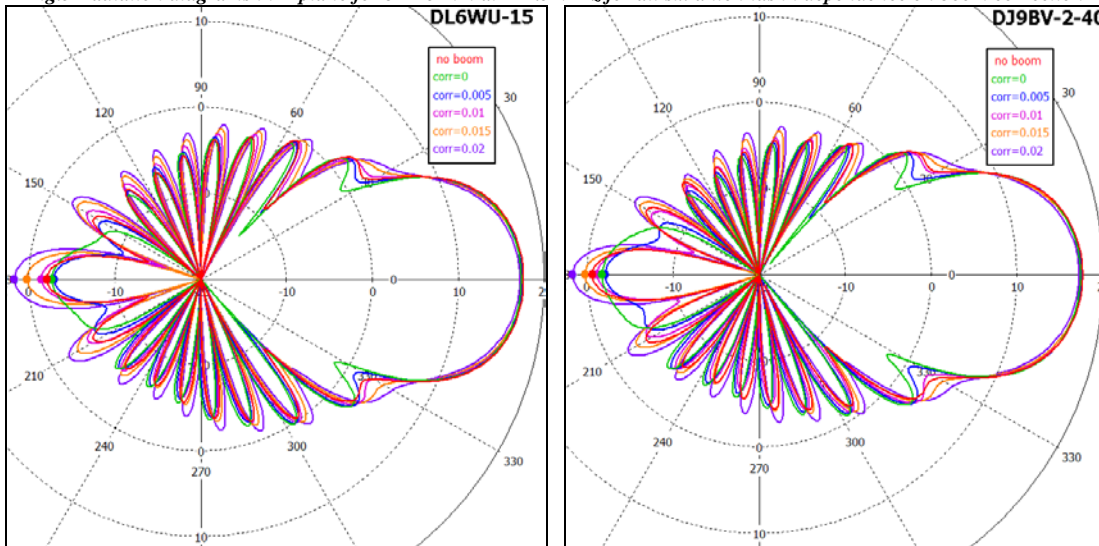
Fig.5 Radiation diagrams in E plane for br=15 mm at 144.5 MHz for all six antennas in dependence on boom correction
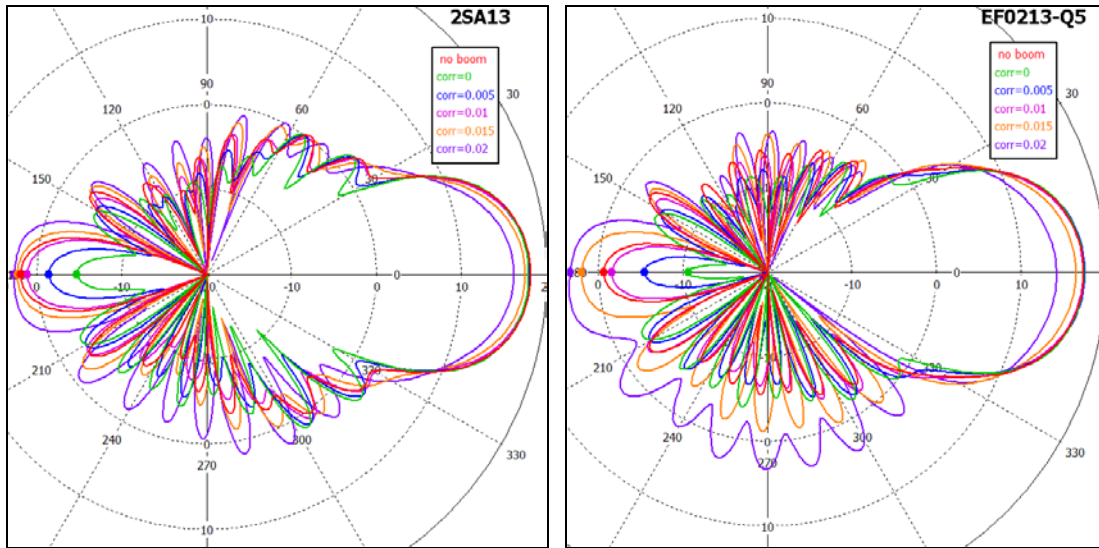
Fig.6 Radiation diagrams in H plane for br=15 mm at 144.5 MHz for all six antennas in dependence on boom correction

Conclusion

In this paper we presented simulations and analyses of various radius conductive boom influence on antenna when elements are not insulated from boom and passing trough it. This element mounting method produces the highest possible boom impact and antenna response and its performance stability are the best turned out.

Various boom diameter as well as various *boom correction* values effects on antenna input return loss, broadband directivity, antenna Q factor and radiation pattern for different antenna designs were compared. Good correlation between antenna average Q factor and these effects were found.

Table 1

Antenna	Optimal *Boom Correction* for Used Antenna Boom Radius [mm]			
	Parameter	10	15	20	25
DL6WU-16	S11	0-15	0-15	0-20	0-20
	BD	0-5	5-10	10-15	15-20
	Q	0-10	5-15	10-20	10-20
	common	**0-5**	**5-10**	**10-15**	**15-20**
DJ9BV-2-40	S11	0-10	0-15	0-20	0-20
	BD	0-5	5-10	10-15	15-20
	Q	0-10	5-15	10-20	10-20
	common	**0-5**	**5-10**	**10-15**	**15-20**
K1FO-16	S11	0-5	0-10	5-15	10-20
	BD	0-10	0-10	10-15	15-20
	Q	0-5	0-10	0-10	0-20
	common	**0-5**	**0-10**	**10**	**15-20**
DK7ZB-12-6	S11	0	0	0-5	0-10

	BD	0	0-5	5-10	10-15
	Q	0	0-5	0-10	0-10
	common	**0**	**0**	**5**	**10**
	S11	0	0	0-5	0-10
2SA13	BD	0-5	0-5	0-10	10-15
	Q	0	0	0-5	0-10
	common	**0**	**0**	**0-5**	**10**
	S11	0	0	0-5	0-10
EF0213-Q5	BD	0	0-5	5-10	10-15
	Q	0	0	0-5	0-10
	common	**0**	**0**	**5**	**10**

It was confirmed once again that antenna Q factor is an important parameter which defines antenna susceptibility to boom effects, but also extent of *boom correction* effects! It is evident that *boom correction* of Yagi antenna depends very much on its design, i.e. Q factor value and that is **not** the same for all types of Yagi antennas as believed so far! From the results summarized in Table 1 it is obvious that for low Q antennas, with elements passing through the boom and electrically bonded to it, a "general rule of thumb" correction of about 25-45% of boom diameter is quite accurate. Antennas designed by DL6WU, DJ9BV and K1FO follow this rule with very good accuracy. In addition to that they are very tolerant to exact *boom correction* value and even wrong *boom correction* will not make serious harm to antenna performances!

Antennas with high Q factor need much smaller *boom correction* values which are about 2 to 3 times less than correction for low Q antennas! Besides that, they are not so tolerant and need quite exact *boom correction* value to be applied for optimum compensation of antenna performances. From results in Table 1 we can see that using "general rule of thumb" *boom correction* for high Q antennas most often gives suboptimal antenna performance compensation.

It seems to us that 'price' which some high Q antennas must pay for a little higher directivity of 0.5 dB at the most, is very 'expensive'! ☺

References:
1. Dragoslav Dobričić, YU1AW, **Boom Distance Influence on Yagi Antenna**, *antenneX*, August 2009, Issue No. 148.
2. Dragoslav Dobričić, YU1AW, **Boom Radius Influence on Yagi Antenna**, *antenneX*, June 2009, Issue No. 146.
3. Dragoslav Dobričić, YU1AW, **Boom Influence on Yagi Antenna**, *antenneX*, May 2009, Issue No. 145.
4. Dragoslav Dobričić, YU1AW, **Yagi Antenna Design Sensitivity in Practice**, *antenneX*, November 2008, Issue No. 139.
5. Dragoslav Dobričić, YU1AW, **Yagi Antenna Q factor**, *antenneX*, July 2008, Issue No. 135.

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.