Yagi Antenna Elements Correction for Square Boom

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Introduction

In the previous December 2009 article **[1]** we showed how the boom caused influences on elements passing through a round tube metal boom and also if they were not insulated from it. Investigation results, presented in this article, will show what the difference is if we use a square tube boom instead of round one.

We know that the presence of a conductive boom and its diameter value have an influence on a Yagi antenna and change both the antenna radiation pattern and input impedance. For this investigation we used all other parameters and dimensions as in our previous article **[1]** except that instead of round tube boom we used square tube boom with dimension **a = 2 br** or **br = a/2** where *br* is boom radius of round tube boom in previous article, as shown on Fig. 1.

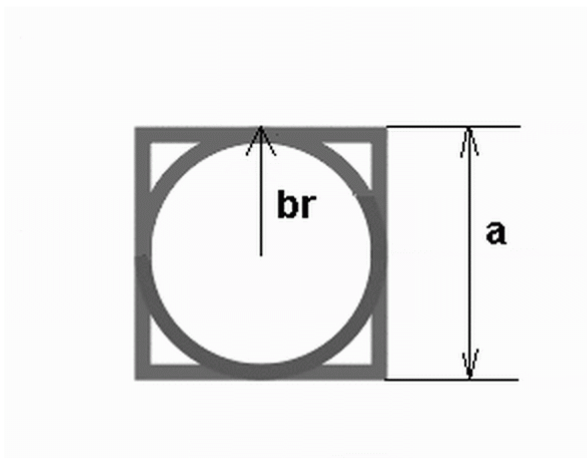

Fig.1 Square tube boom dimension in reference to round tube boom

Different Yagi antenna designs show different sensitivity to environmental impacts and it is expected that an antenna boom with different cross section shape can show different effects on different antenna designs as well.

In this investigation we will examine how square tube metal boom influences antenna performance when elements without insulation are passing through it.

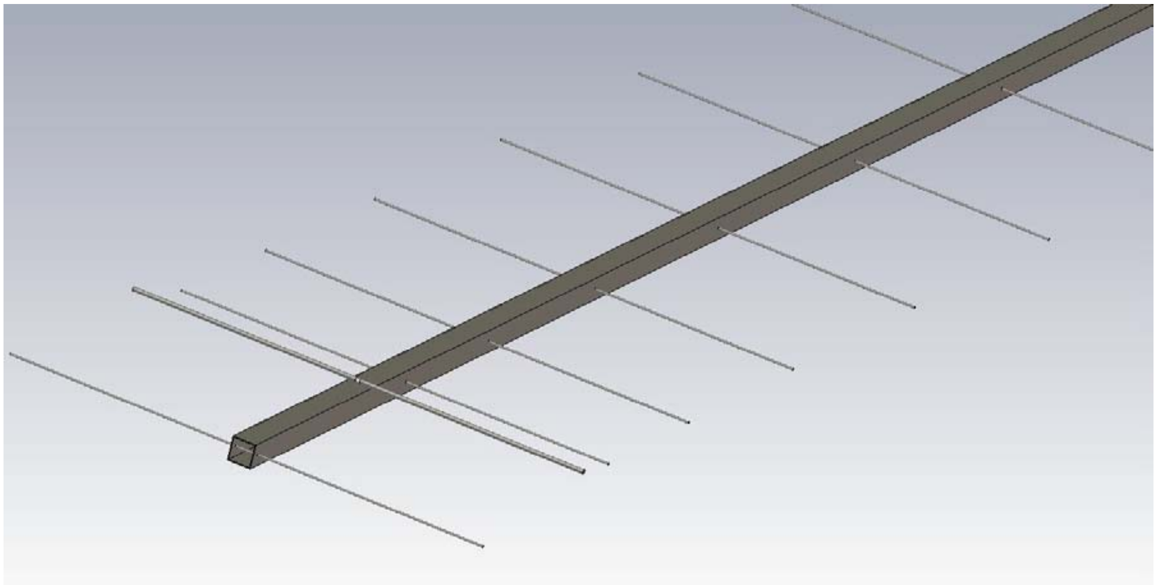

Fig.2 Simulation model of Yagi antenna with non insulated elements passing through square metal boom and elevated driven element

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 a boom's impact and value of the necessary elements length correction.

For elements passing through the boom and electrically bonded to it, a general rule of thumb correction is about 25-45% of boom diameter. In the previous article, we found that this general rule of thumb for boom correction, with non insulated elements passing through the boom, is quite accurate for antennas with low Q factor. But for antennas with higher Q factor, we found that boom correction value should be less for an antenna's optimum performance.

Simulation conditions

All six Yagi antennas that were used in past articles **[1, 2** and **3]** were simulated again under the same conditions except that a square boom was used instead of a round one. A variable thickness conductive square tube boom was placed exactly at the axis of antenna so that the elements pass right through the center of square tube boom. The boom axis and elements axis are crossing under right angles (Fig. 2).

It is similar as in our previous investigation and it represents a Yagi antenna simulation with elements that are not insulated from a boom and passing through the square conductive boom. Simulation conditions were very similar to a practical situation when a single antenna, with conductive square tube boom and elements electrically bonded to it, is mounted on the top of a very tall and slim pole. However, as in the previous article, the pole itself is not a part of simulation model.

The elements length has been changed to compensate for boom effects. This lengthens of elements known as *boom correction* was varied from 0 to 20 mm. Correction was applied on all elements except the driven dipole because it is not passing through the boom. The driven dipole element axis is elevated above the boom's top most surfaces for about one half of the boom dimension ***a***. During simulations, boom dimension ***a*** changed from 20 to 50 mm (***br*** = 10…25 mm) as a parameter. The thickness of the metal boom tube wall is set to be 2 mm.

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

For this task the antenna simulation software based on Finite Integration Technique has been used once again **[4]**. Similarly as in the previous article, boom dimension and elements *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 whether there is any difference between round and square boom influence on antenna parameters and also what would be the best value of *boom correction* and how it changes with different boom dimension and antenna design.

Simulation results

The magnitude of boom influence and thus antenna parameters change depending on boom thickness and it is necessary to apply different *boom corrections* on the element lengths as compensation for various boom dimensions.

However, boom influences as well as *boom correction* effects, on different antenna performances are usually also different. As a result, we have to choose such *boom correction* value that will best compensate boom effects on some specific parameter. Other antenna parameters will also be 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. 3 show input return loss mean value dependence of applied *boom correction* for various boom dimensions.

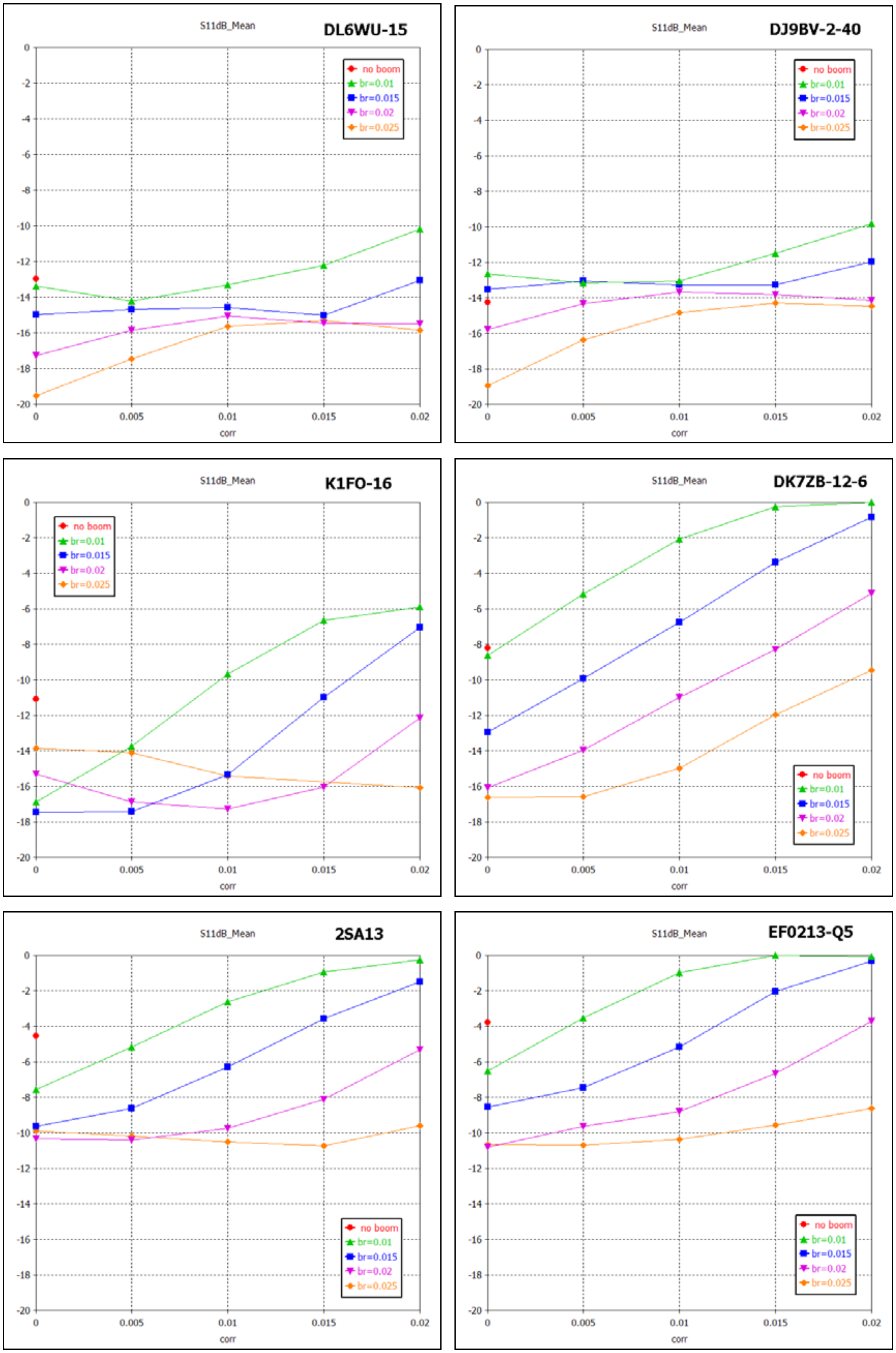

Fig.3 Antenna input return loss mean value in 144…146 MHz band for different square boom dimension br=a/2 and corrections (corr)

If we compare these results with similar diagrams from the previous article, we can see that the antenna input return loss for square boom is very similar as with a round boom. The only noticeable difference, common for all antennas, is that for thicker square booms input return loss mean value is a little bit better than with round booms.

We can see again that only DL6WU and DJ9BV antennas are almost completely independent on applied *boom corrections* and retain good input return loss for all boom dimensions and corrections of elements length. This demonstrates their very tolerant design insensitivity to severe boom influences and change of antenna element dimensions.

K1FO antenna also once again demonstrates very good and expected behavior for boom dimension change and necessary *boom correction*. This antenna is a little bit more critical about accurate *boom correction* value for thinner booms than the already mentioned two antennas.

Other three antennas, due to their narrow SWR working bandwidth, have lower input return loss mean value. Among them once more DK7ZB antenna has better overall input return loss mean value than other two antennas, especially for thicker booms. These higher Q factor antennas showed less sensitivity to exact value of *boom correction* only when they were used with larger boom dimensions.

From results on Fig. 3 it is obvious that antennas with lower average Q factors have less variation and overall difference of input return loss due to variation of boom dimension and applied *boom correction* in frequency band 144…146 MHz.

Insensitivity and tolerance of low Q factor antennas to exact value of *boom correction* for corresponding boom dimension is once again clearly noticeable.

Broadband directivity

Antenna broadband directivity mean value curves given on Fig. 4 follow similar trend as input return loss mean value curves on Fig. 3.

When we look at diagrams in the previous article **[1]** and compare them with diagrams presented in this article, we can see some interesting facts. For antennas with low Q factor the broadband directivity curves for both boom cross section shapes are almost identical. It is expected from tolerant antennas that such a small change in boom cross section shape cannot change their performance in any larger extent.

But for higher Q factor antennas, change of broadband directivity curves with change of boom cross section shape is considerable bigger. This behavior is expected from antennas with higher sensitivity to environmental influences **[5]**. It is interesting that even such a minor change on antenna construction produces such a noticeable difference in performances!

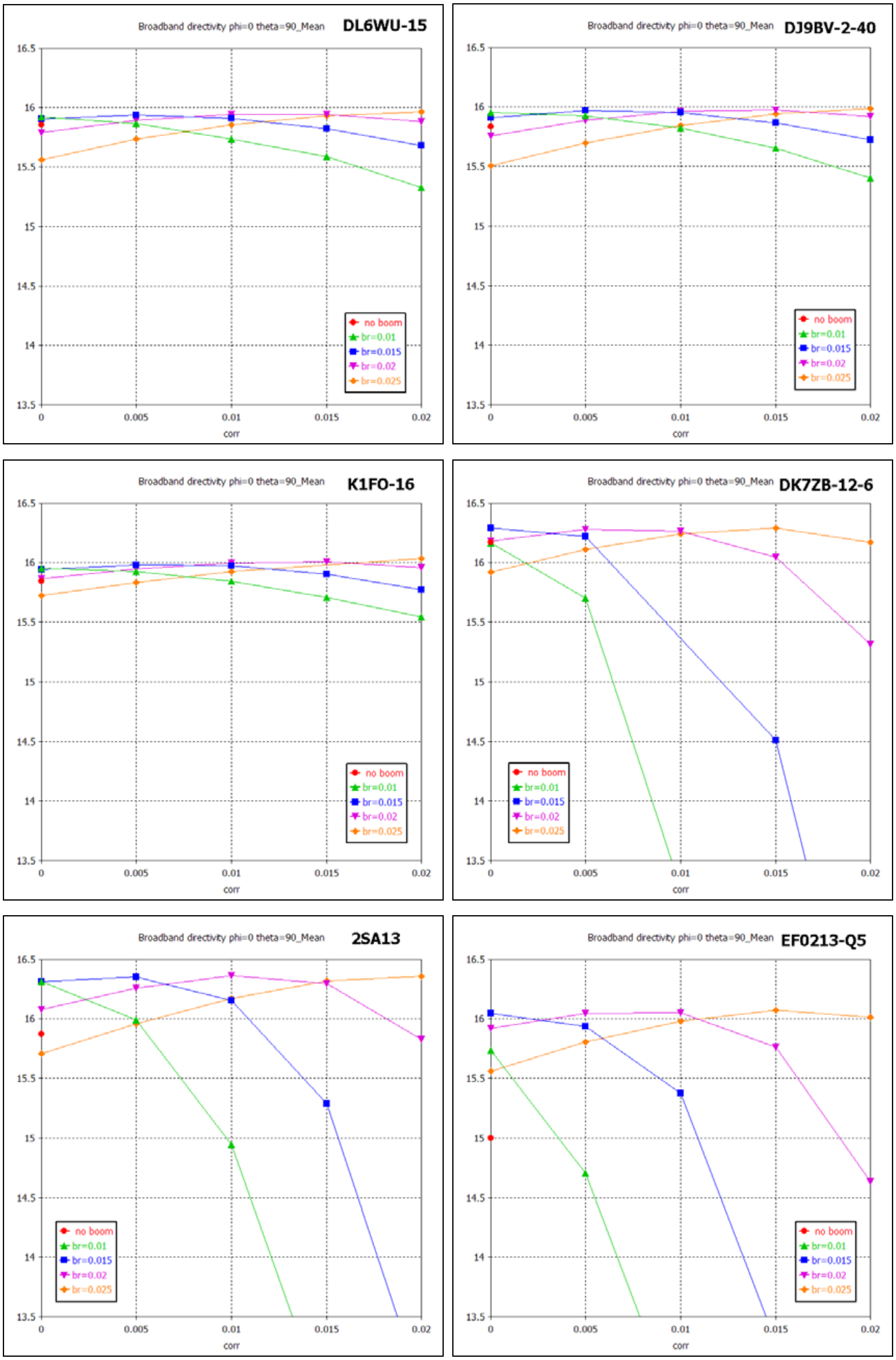

Fig.4 Antenna broadband directivity mean value in 144…146 MHz band for different square boom dimension br=a/2 and corrections (corr)

As already mentioned K1FO, DJ9BV and DL6WU antennas once again showed high stability of broadband directivity mean value all over changes of boom dimension and *boom correction* of element lengths. They preserved their high directivity in whole band even when they were compensated with wrong *boom correction* for square boom dimensions used, or even not compensated at all! Change of the boom's cross section shape is absolutely of no importance for the low Q factor antennas directivity. Such behavior is quite expected. If antenna is so tolerant to elements length change, isn't it quite predictable to be also tolerant to minor changes of booms cross section shape?

The next two antennas, 2SA13 and DK7ZB, once again showed a little higher directivity (up to 0.5 dB) than other antennas when they are exactly corrected for optimum directivity performance for the antenna boom dimension used. This *boom correction* value again appeared that has to be less than for low Q factor antennas.

And finally, YU7EF antenna shows once again similar directivity as three low Q factor antennas but with very big change of performances for different boom dimensions and applied *boom corrections*. For this antenna *boom correction* value also appeared that has to be less than for low Q factor antennas.

Diagrams on Fig. 4 show that, similarly as in the previous article, 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. Even more, they show that a trivial construction change from round to square tube boom also changes their broadband directivity performances in much higher degree than for low Q factor antennas.

Antenna Q factor

As we mentioned in the previous article, boom influence, together with *boom correction* effects, changes all antenna performances and, among them, changes antenna Q factor. In our earlier investigations we noticed and reported that good antenna design manifests its stability and tolerant behavior by a small change of its Q factor under some environmental attack. So, we concluded that 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 antennas probably will behave under various environmental influences **[5, 6]**. This fact was confirmed many times in almost all our past simulations of antennas under various environmental influences **[1, 2, 3** and **5]**.

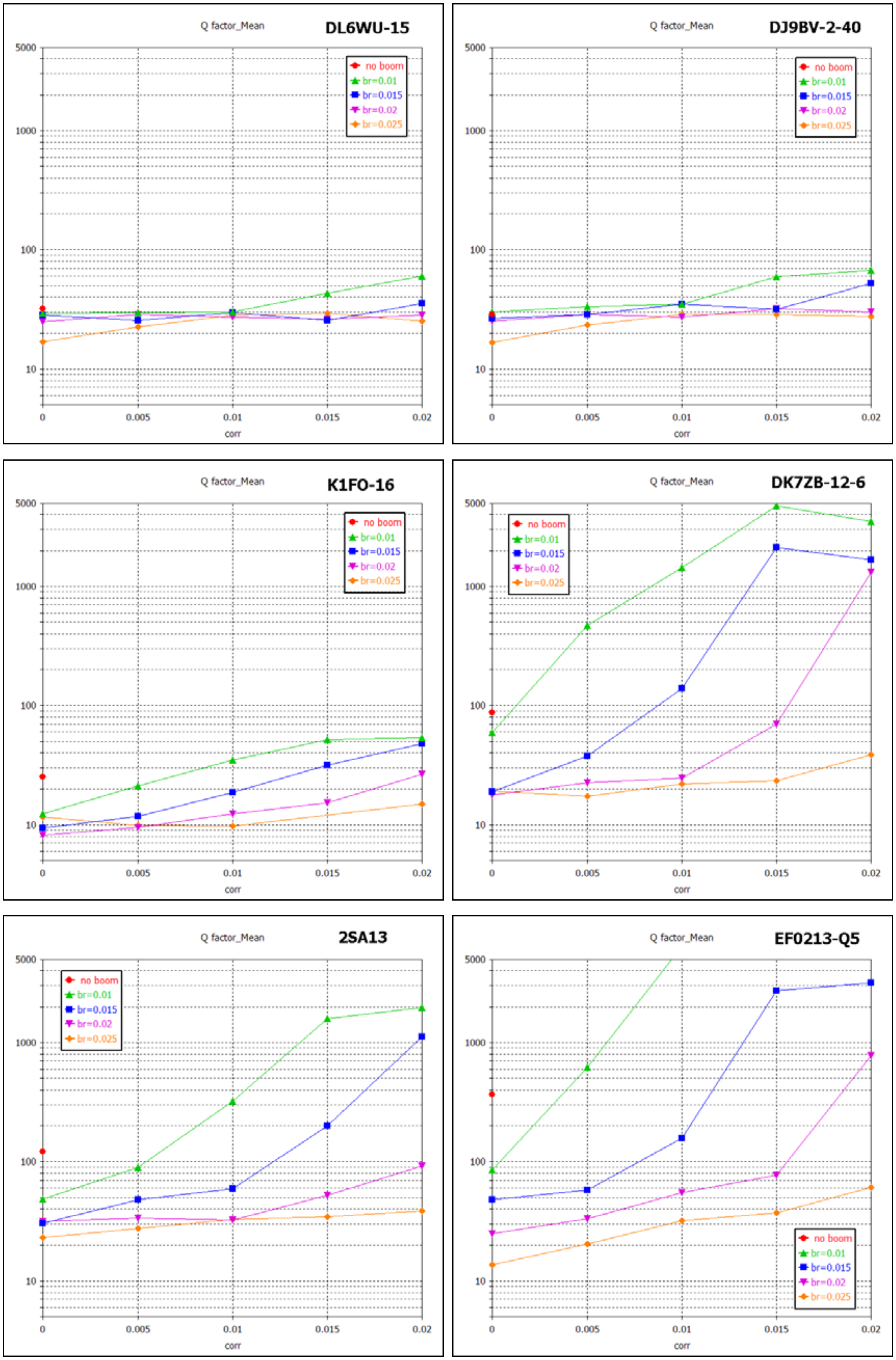

Fig.5 Antenna Q factor mean value in 144…146 MHz band for different square boom dimension br=a/2 and corrections (corr)

According to results of many simulations of different antennas under many different environmental attacks, it is noticeable that it is **not** enough that the antenna initially has low Q factor value under idealized simulated environmental conditions to be considered a good tolerant antenna. It is necessary to let the antenna show how it behaves in real or simulated conditions of some severe environmental impact and check how this antenna changes its initial Q factor at that time. This difference of Q factor values gives much better insight into antenna quality! Good antennas usually have small difference of obtained initial Q factor value in idealized simulated conditions and Q factor value under some serious environmental attack **[5]**.

Here, once again, we can see confirmation of this fact. In this investigation, antennas that show very stable and low Q factor mean value show also very tolerant behavior preserving good input return loss and stable high directivity mean value under all circumstances. Minor changes in its construction, such as change of the boom's cross section shape, doesn't produce any significant change of antenna performances.

As it is obvious from diagrams on Fig. 5, DL6WU, DJ9BV and K1FO antennas show once again 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. For these antennas change of boom's cross section shape is something negligible regardless of applied boom dimension and *boom correction* of element lengths.

Other three antennas, similarly as in previous investigation with round boom, have relatively low and flat Q factor only if they are used with very large dimension boom! It seems that very large dimension booms lower their Q factor and broaden their broadband directivity and working bandwidth.

Antenna pattern

All antenna patterns were again taken on frequency 144.5 MHz. Because of limited article length it is not possible to publish radiation patterns of all six antennas for all simulated boom dimensions. But as an illustration of each particular antenna behavior with various *boom corrections* we decided to publish only patterns for boom dimension *a* = 30 mm which is most frequently used for this antenna length.

Polar plots of antenna directivity in E and H plane are presented on Fig. 6 and Fig. 7. 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 element mounting. Also, there is very strong parameter dependence on whether an antenna is built exactly as it was presented by its model in computer simulations and optimization. Besides, different antenna designs behave differently under the same conditions depending on its Q factor, i.e. sensitivity to environmental influences.

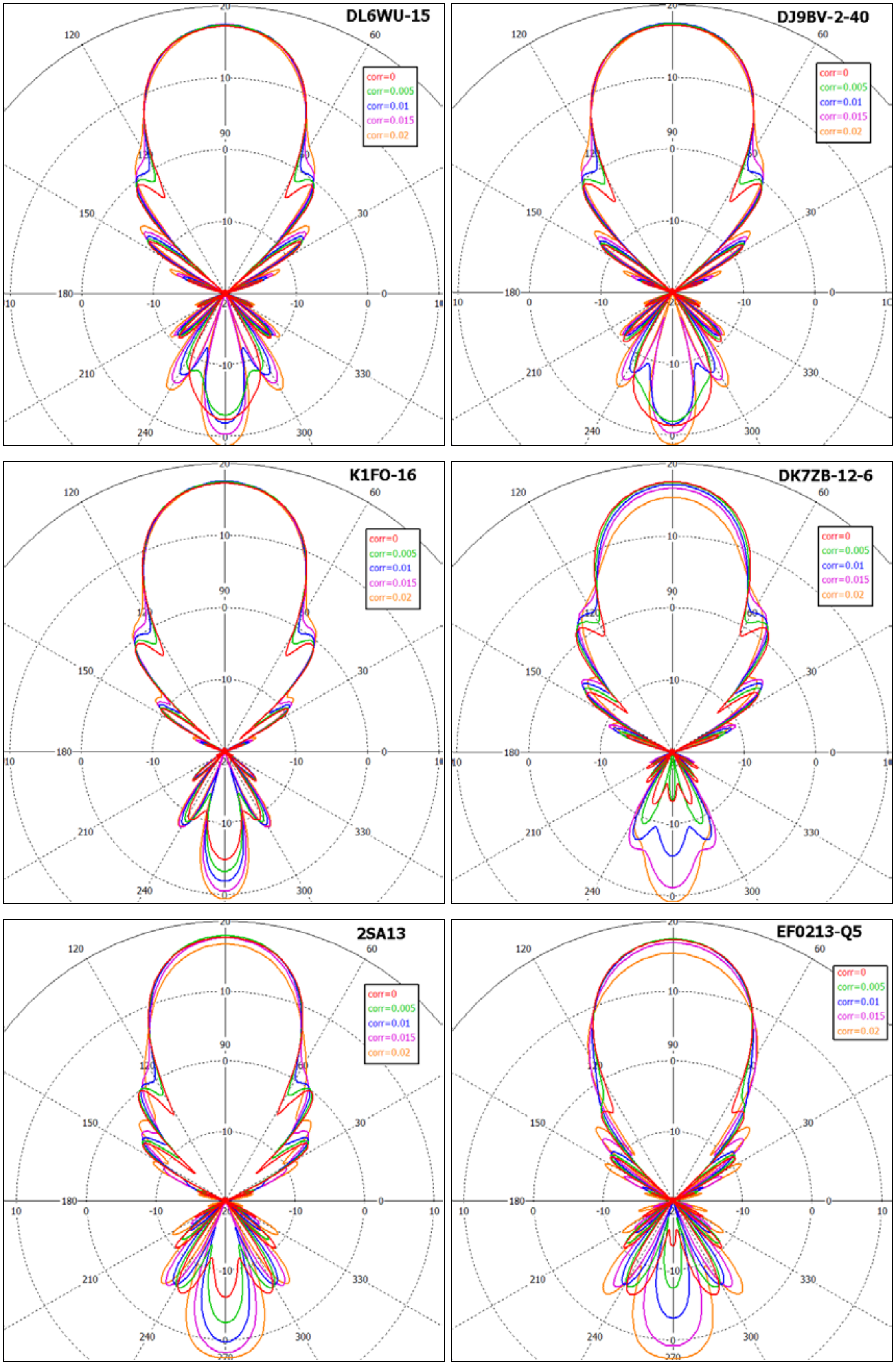

Fig.6 Radiation diagrams in E plane for br=15 mm at 144.5 MHz for all six antennas in dependence on boom correction

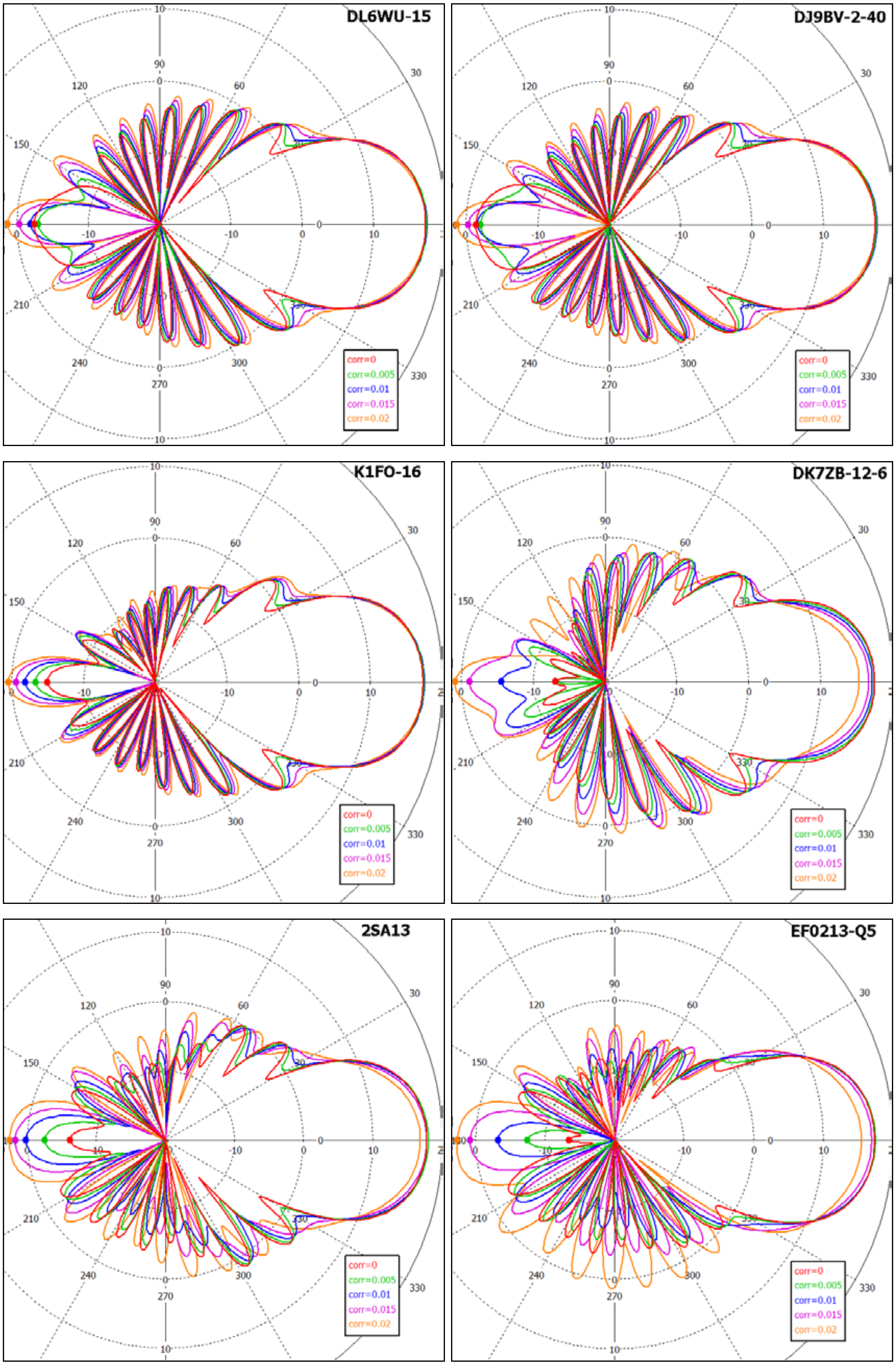

Fig.7 Radiation diagrams in H plane for br=15 mm at 144.5 MHz for all six antennas in dependence on boom correction

However, with non insulated elements mounted through metal boom we have highest possible interaction between boom and elements. Because of this highest possible boom impact on the stability of antenna performances, even the slightest change in boom dimension or even cross section shape can significantly reflect on antenna performances!

Boom influence optimum compensation, for various boom dimensions, by the value of *boom correction* of three important parameters: maximum broadband directivity (BD), minimum Q factor (Q) and maximum input return loss (S11) mean values 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 of all parameters in the same time.

Table 1

Antenna	Optimal *Boom Correction* for Used Antenna Square Boom Dimension ***a*** [mm]				
	Parameter	**20**	**30**	**40**	**50**
DL6WU-15	S11	0-10	0-10	0-20	0-20
	BD	0-10	5-15	10-20	15-20
	Q	0-15	0-15	0-20	0-20
	common	**0-10**	**5-10**	**10-20**	**15-20**
DJ9BV-2-40	S11	0-15	0-15	0-20	0-20
	BD	0-10	5-15	10-20	15-20
	Q	0-10	0-15	0-20	0-20
	common	**0-10**	**5-15**	**10-20**	**15-20**
K1FO-16	S11	0-5	0-15	0-20	0-20
	BD	0-10	0-15	5-20	10-20
	Q	0-5	0-10	0-15	0-20
	common	**0-5**	**0-10**	**5-15**	**10-20**
DK7ZB-12-6	S11	0	0	0-5	0-10
	BD	0	0-5	5-10	10-15
	Q	0	0-5	0-10	0-15
	common	**0**	**0**	**5**	**10**
2SA13	S11	0	0	0-5	0-15
	BD	0	0-5	0-10	15-20
	Q	0	0-5	0-10	0-20
	common	**0**	**0**	**0-5**	**15**
EF0213-Q5	S11	0	0	0-5	0-10
	BD	0	0-5	5-15	5-20
	Q	0	0-5	0-10	0-15
	common	**0**	**0**	**5**	**5-10**

Conclusion

In this paper we presented simulations and analyses of various dimensions of square conductive boom influence on antennas when elements are not insulated from boom and passing through it. This element mounting method produces the highest possible boom impact and antenna response and its performance stability are the best results. In this article we also compared how the same antennas behave when they are built with square instead of round tube boom. It is shown that this seemingly unimportant small change in construction of antenna can sometimes give noticeable changes in antenna performances.

Various square boom dimensions 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.

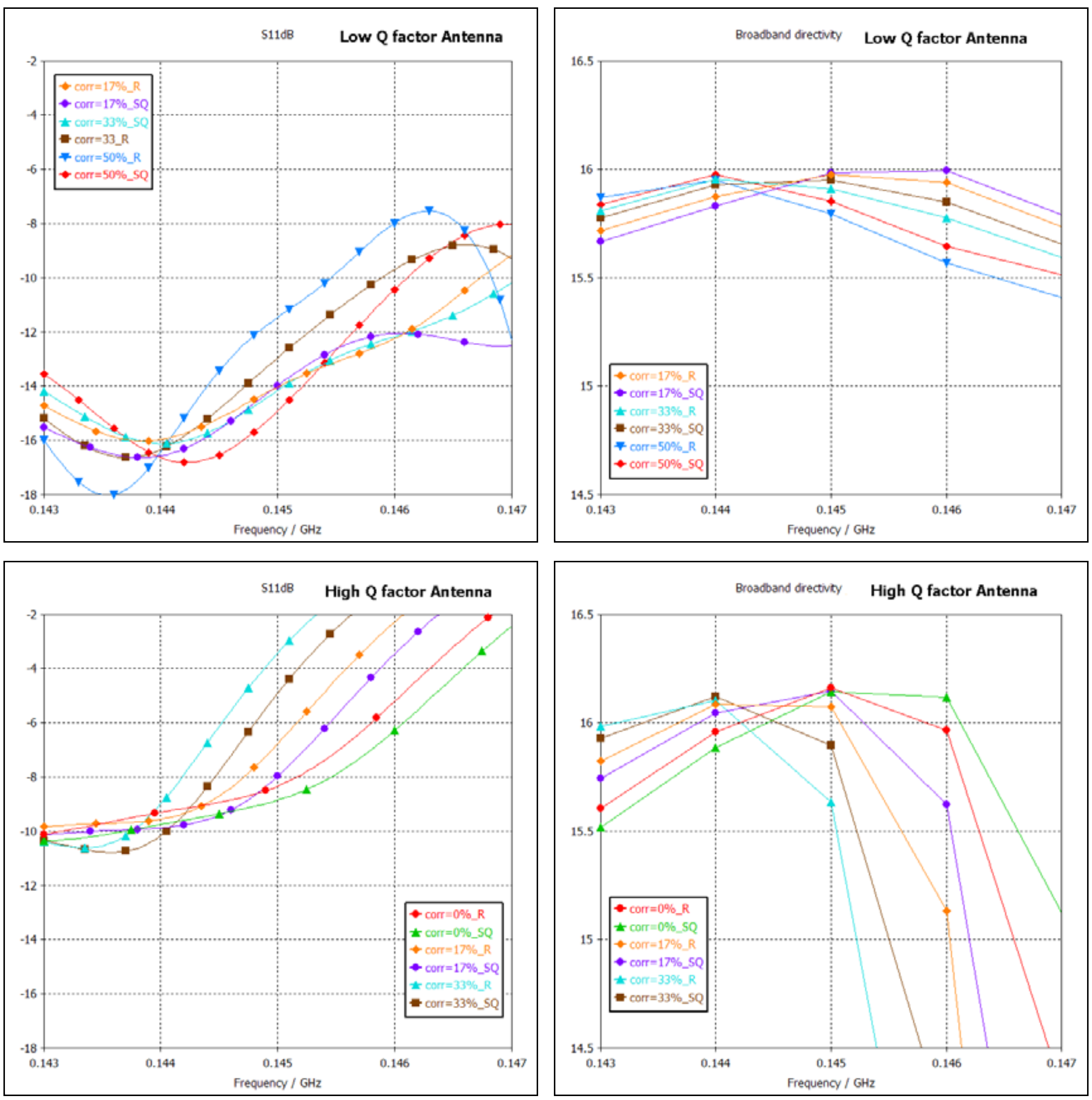

Fig.8 Comparison of input return loss and broadband directivity for round (R) and square (SQ) boom (a=2br=30 mm) and different applied corrections (corr) in % of boom dimension* a*, for low and high Q factor Yagi antennas.

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 as it is obvious from results in Table 1 and diagrams on Fig. 8!

Comparative diagrams for 30 mm round (R) and square (SQ) tube boom antennas are presented on Fig. 8. They show input return loss and broadband directivity of two antennas with rather different Q factors. We can see how antenna parameters shift depending on boom cross section shape used and applied *boom correction* values given in % of boom dimension *a*.

It is evident that *boom correction* of Yagi antenna depends very much on its design, i.e., its Q factor value and it is **not** the same for all types of Yagi antennas as believed so far! Even more, it is not always the same for optimum compensation of all important antenna parameters!

From the results summarized in Table 1 it is obvious that for low Q factor antennas, with elements passing through the boom and electrically bonded to it, a “general rule of thumb” correction of about 25-45% of boom dimension 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! So the small change in boom’s cross section shape almost didn’t influence their characteristics at all.

Antennas with high Q factor need much smaller *boom correction* values which are about 2 to 3 times less than correction for low Q factor antennas! It is quite expected that the same lengthening of elements does not produce the same effects on low and high Q factor antennas. Besides that, they are not so tolerant and need quite exact *boom correction* value to be applied for optimum compensation of particular antenna performance. From results in Table 1 we can see that using “general rule of thumb” *boom correction* for high Q factor antennas most often gives suboptimal antenna performance compensation. **-30-**

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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 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.