Yagi Antenna Boom Influence on UHF

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Summary of various influences

Our studies of various influences on Yagi antenna performances have shown that some "rules of thumb" and "common beliefs" are very often valid only in a limited range.

From several previous articles **[1, 2, 3, 4, 5, 7** and **8]** we can see that many environmental effects can spoil antenna performance, but all these effects are neither equally severe nor are different antennas equally susceptible to them.

So far we investigated how the boom distance from elements, boom dimension, boom cross section shape and element mounting methods influence the Yagi antenna's performances. Related to the element mounting methods, we also investigated optimum *boom correction* for different mounting methods and different antennas. Besides the mentioned boom effects, we also investigated how the presence of coaxial cable and its position relative to antenna elements influence of the antenna radiation diagram (or pattern) and other important performances.

Influences on UHF antenna

All these investigations were conducted on VHF antennas for frequency band 144…146 MHz. Obtained results can be extrapolated to other frequencies provided that we take into account dimensions proportionality and other specific circumstances of particular research. Using this opportunity we can conclude with very high probability how similar Yagi antennas will behave at some other frequency. This is particularly important for UHF Yagi antennas where working frequency is several times higher and thus boom diameter and other antenna dimensions become a more considerable part of the working wavelength. Consequently, influences can be much more emphasized and very often some different construction solutions must be applied on Yagi antennas for higher UHF bands.

Influence of metal boom near elements

A metal boom near an antenna's elements produce a frequency shift of antenna performances. Magnitude of frequency shift depends on boom distance and boom diameter. Larger distances and smaller boom diameters produce less influence.

On **Fig. 1** we can see how various diameter metal booms with fixed distance of 7 mm between the boom's top-most surface and elements axis influence a Yagi antenna and shift its performances on higher frequencies depending on boom diameter.

On VHF, boom diameter is usually only 1 to 2.5 % of the antenna's working wavelength and frequency shift due to metal boom presence is only about 1 to 1.5 % of working frequency, depending on antenna type. On 2 m band this is about 1.5 to 2.5 MHz.

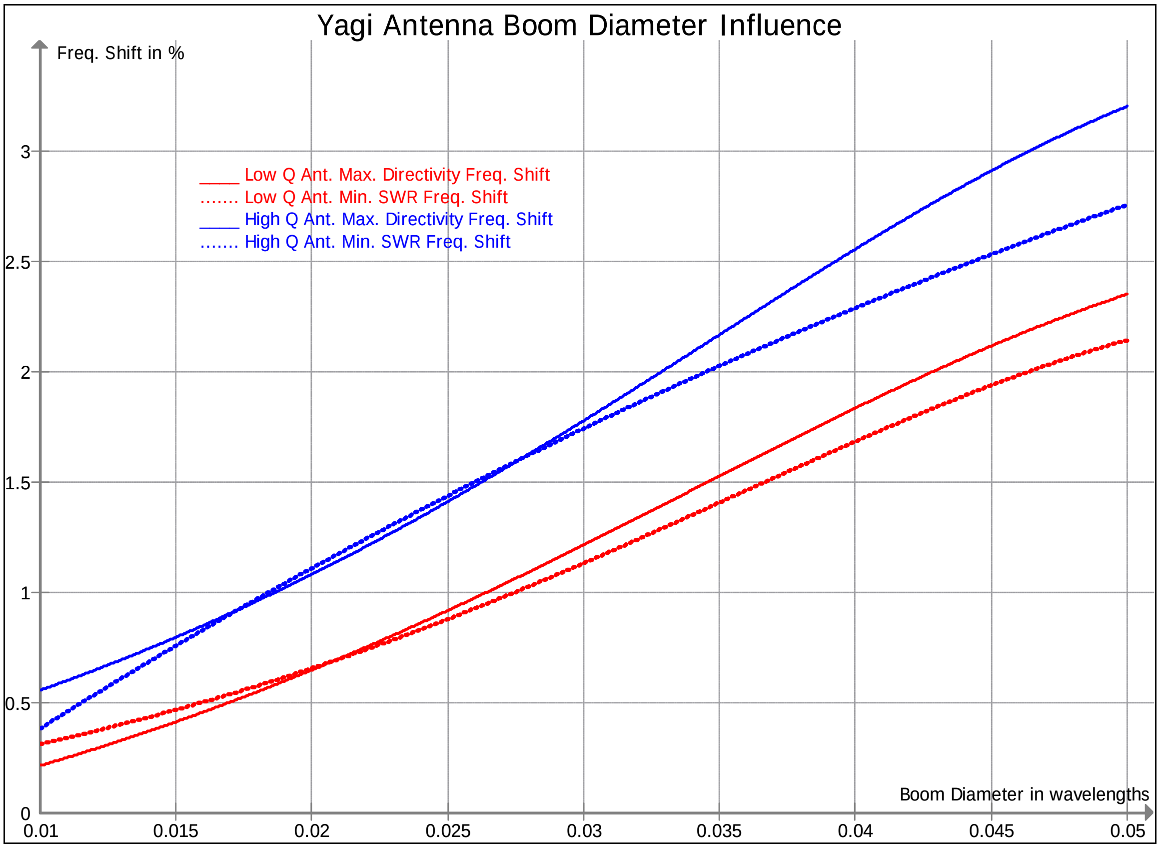

Fig. 1

But on UHF, for example on 23 cm band, minimum usable antenna boom diameter is over 5 % of wavelength and corresponding minimal frequency shift is over 2 or over 3 %, depending on antenna type, and these amounts to a frequency shift of over 26 or 38 MHz!

On the other hand, 7 mm fixed elements distance from boom is about 0.0034 on 145 MHz, but on 1296 MHz it is about 0.03 wavelengths or about 9 times larger. For valid extrapolations we have to use the same distance in wavelengths on the 23 cm band as on 2m band and this amounts 0.8 mm. Thus we can expect a frequency shift of 26 to 38 MHz on 23 cm band with 0.8 mm distance between boom and antenna elements. With larger distances we can expect a lesser amount of frequency shift, according to the curves trend on **Fig. 2**.

DX portion of the 23 cm band is practically the same as on 2 m band, and amounts to about 0.5 MHz. Maximum allowable frequency shift of 0.5 MHz, which guarantee that intended antenna performances will stay in DX part of a band, on 145 MHz amounts about 0.34 %, but on 1296 MHz it amounts 0.038 %, or approximately 9 times less!

The boom influences on an antenna produce frequency shifts which are just opposite of those that the moisture on antenna elements does. Conductive boom presence and its effects partly “compensate” the moisture 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 **[6]**.

Antenna performances calculated by an NEC program without considering any boom effects and built on boom of nonconductive material suffer more due to moisture influence than the performances of the same antenna built on a conductive boom. This is due to lack of a conductive boom “compensating” effects on wet antenna performances.

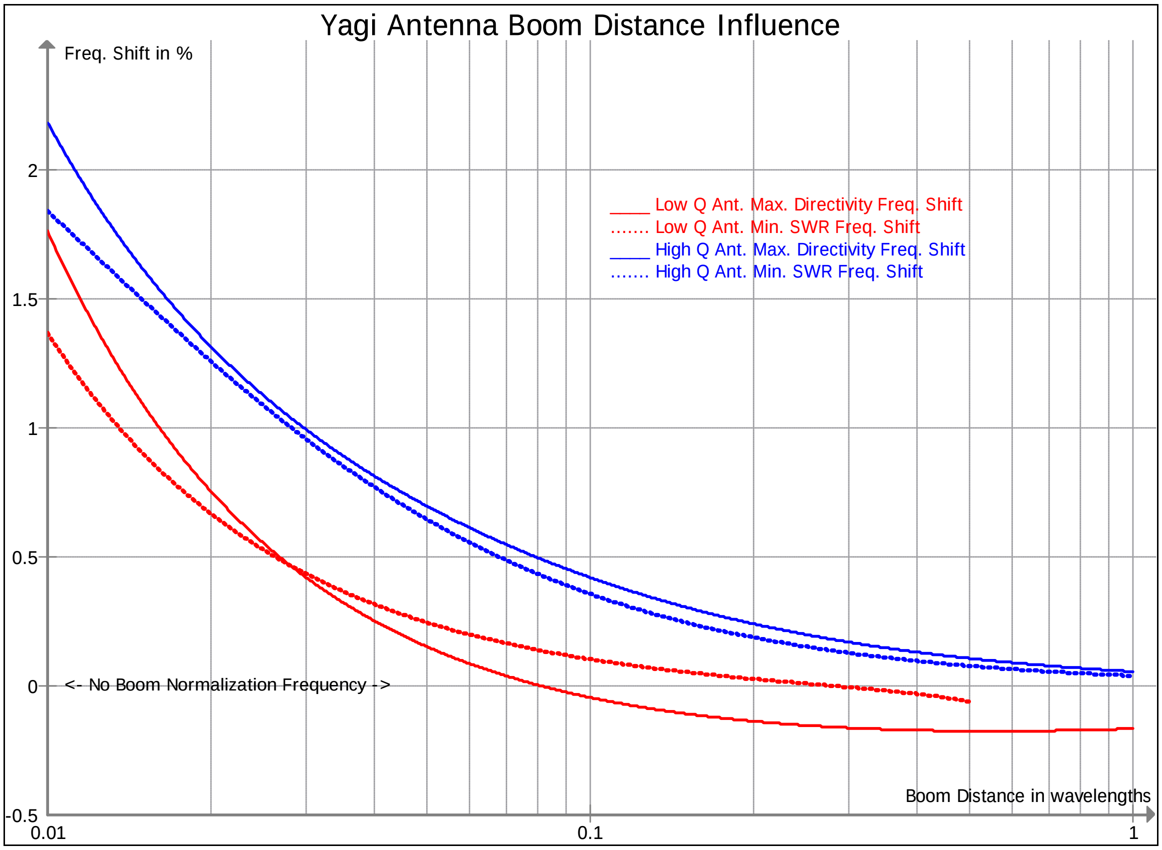

Fig. 2

The diagram on **Fig. 2** presents influence of fixed diameter boom of 50 mm on various distances from the antenna elements. Usual height of insulator on which elements are mounted on 2 m antennas is about 20…30 mm or about 0.01…0.015 wavelengths. Frequency shift of antenna parameters due to boom influence is in the range of above 1 to 2.2 % or 1.5 to 3.3 MHz on 145 MHz band, and depending on antenna design. On frequency of 1296 MHz the same distance between boom and elements is 0.087 to 0.13 wavelengths and corresponding frequency shift is between -0.15 to +0.5 % or -2 to +6.5 MHz depending on antenna type and insulator height.

On the other hand, fixed boom diameter of 50 mm on 144 MHz is 0.024 while on 1296 MHz is 0.217 wavelengths. For correct extrapolations on 23 cm band we have to use the same boom diameter in wavelengths as on 2m and this is equal to 5.5 mm. It means that we can get a frequency shift of -2 to +6.5 MHz, depending on antenna design, only with very small boom diameter of 5.5 mm. For bigger boom diameters corresponding frequency shift will be larger according to the trend of curves on diagram given on **Fig. 1**.

Elements diameter is also a parameter that can control boom influence in some lesser extent and for complete picture we should recalculate its diameter. However, we usually construct our 23 cm antennas with thinner elements so that is already partially done.

For the purpose of our interpolations we assumed that the insulators which hold elements have no influence on antenna parameters on working frequencies.

The result of conducted simulations show that the boom influence is much more long-range than the general rule of thumb suggests. It is 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.

It is very interesting that for some antennas, at large distances of 200 − 300 mm between boom and elements, frequency shift of maximum input return loss becomes very small compared to input return loss of the same antenna without a boom, but directivity and radiation pattern still differ considerably.

This fact shows that it is not always possible to estimate whether an antenna suffers from some destructive influence from its surrounding by simply measuring antenna input return loss or SWR.

Elements passing through boom and bonded to it

With elements without insulation and mounted through a metal boom, we have the highest possible interaction between boom and elements. As we saw in our previous articles **[2, 3]**, due to this highest possible boom impact on the stability of antenna performances, even the slightest change in boom dimension or even cross section shape could significantly reflect on antenna performances.

This type of element mounting produces extremely high influence of boom on antenna performances. Frequency shift is usually so high that it is necessary to apply length correction to the elements known as *boom correction* in order to preserve intended antenna performances on desired frequency band.

Every antenna parameter (directivity, SWR, Q factor, radiation pattern, etc.) can be separately optimized, but it is also possible to find one or more common correction values that optimize all antenna parameters for the boom diameter used. It is found that all antennas don't have the same correction value or values range for the same boom diameter and that the correction strongly depends on the type of antenna and its Q factor **[2, 3** and **9]**.

The diagram on **Fig. 3** illustrates this difference of average value for common correction which optimizes antenna parameters with specified boom diameter for different type of antennas.

Different Yagi antenna designs show different sensitivity to environmental impacts and it is expected that an antenna *boom correction* also may have different effects on different antenna designs as well. Therefore, this diagram is a confirmation of this expectation and shows that different antennas need different *boom corrections* for same boom diameter.

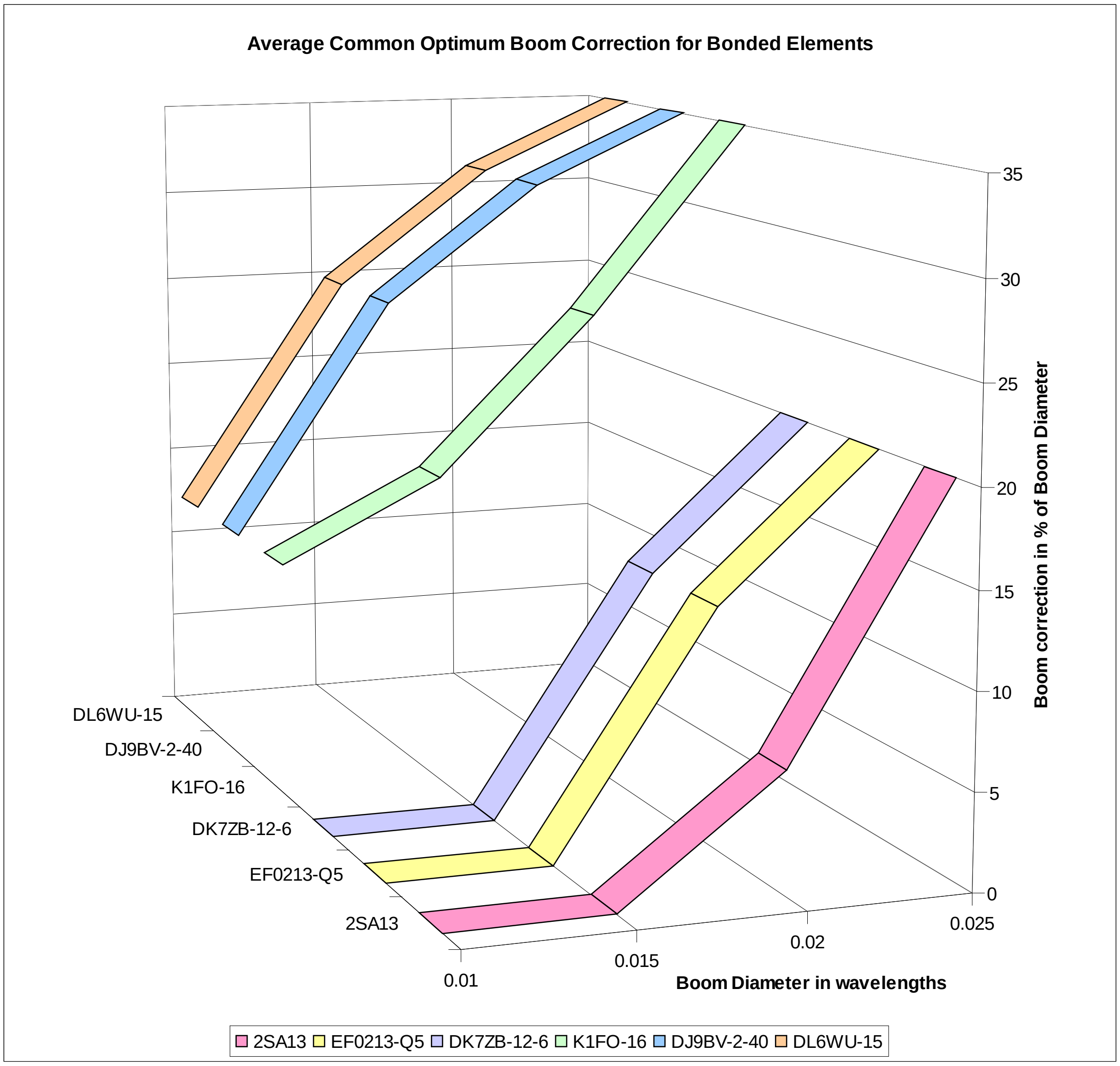

Fig. 3

Under the same conditions we can expect that UHF Yagi antennas also need different *boom corrections* in order to compensate the boom effects. However, due to short wavelength, choice of optimum *boom correction* is much more critical, because of much bigger boom influence and frequency shift. A choice is much easier if the antennas have less critical design and a larger range of possible optimum corrections values.

How big *boom correction* can be?
Another interesting question arises when we think about very high frequency Yagi antennas. What happens when the wavelength becomes so short that every practical boom diameter becomes very large measured in wavelengths? Or, in other words, how far can we go with compensation of very large diameter booms?

Günter, DL6WU first asked this question and also gave his answer by practical measurements. His measurements clearly show that *boom correction* has “saturation” at boom diameter bigger than about 0.07 wavelengths. *Boom correction* value reaches about 65 % of boom diameter and doesn’t change with further boom diameter increasing!
On the first sight it seems as quite “peculiar” antenna behavior and it was very challenging to see how our simulations would correspond to his measurements. Günter kindly provided all data and information about his measurements which were necessary for correct modeling and accurate simulations.

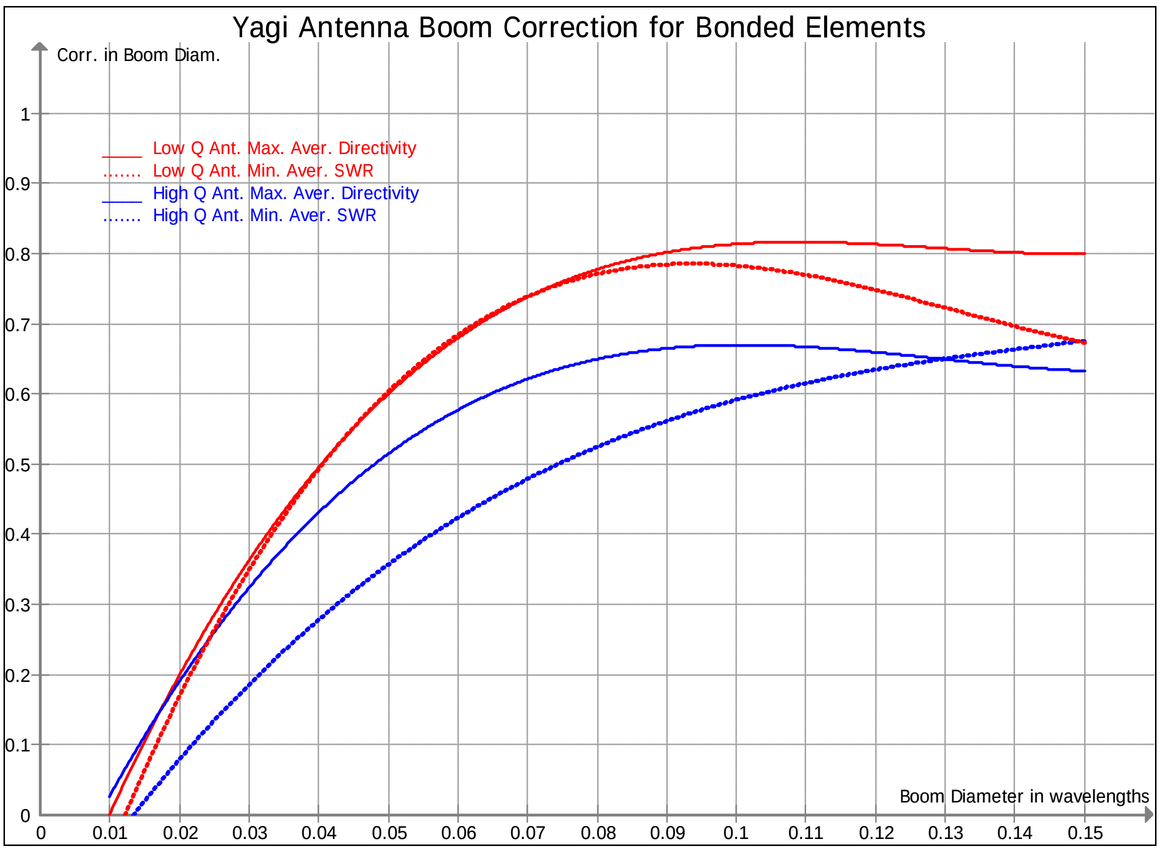

Fig. 4

Simulations of antennas with very big boom diameters that are presented on **Fig. 4** show that for high Q antennas saturation of *boom correction* is at about 65 % of the boom diameter and starts at a boom diameter of about 0.07...0.08 wavelengths, exactly as Günter found in his practical measurements! Low Q antennas have very a similar trend but they reach a little higher percentage of *boom correction*. It is in quite good agreement with the results on **Fig. 3** where low Q antennas have considerably higher average optimum *boom correction*s for the same boom diameters. Even more, since they have much wider range of values that optimally corrects antenna performances these practically measured *boom corrections* percentage are well in the range of optimum compensations values for the given boom diameters. Günter's measurements were conducted on short boom Yagi antenna, while my simulations were done on longer Yagi antennas. Good agreement of measurements and simulations results show that this behavior of Yagi antenna probably is general and it seems that it doesn't depend on boom length.

Elements passing through boom and insulated from it

With elements that are passing insulated through a boom, all of these influences of a metal boom are not so much. The size of a boom influence is less due to an insulation of the elements from the boom, and consequently magnitudes of monitored parameters change are also smaller.

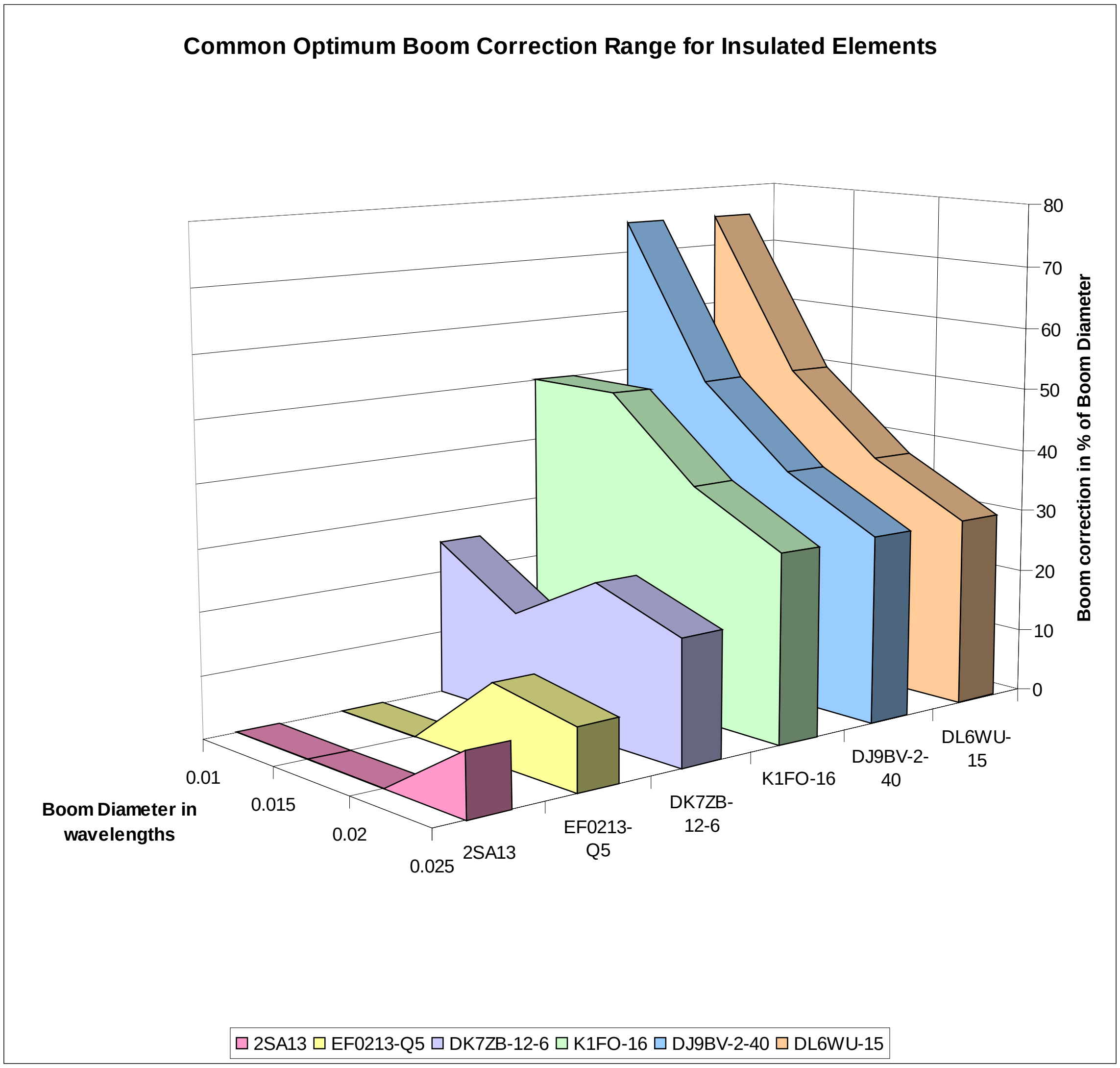

Fig. 5

However, the general trend for all antenna designs is very similar. This clearly shows that antenna susceptibility to environmental influences is determined by its design, and that a magnitude of environmental impact also depends on its construction, i.e., its mounting method of the elements.

The magnitude of boom influence and thus antenna parameters change depends on boom diameter and it is necessary to apply different *boom corrections* on element lengths as compensation for various boom diameters.

Diagram on **Fig. 5** shows range of *boom correction* values for different antennas. From this diagram it is visible that while some antennas can be compensated with an extremely large range of *boom correction* values in order to be optimal, other antennas can be compensated only by one or few *boom correction* values from a very limited and narrow range of values. This gives very good picture about the tolerance level of every particular antenna design.

On high frequencies, where all influences are emphasized due to small wavelength, antennas become more critical, so that tolerant antennas with a wide range of *boom corrections* are more desirable and preferable for use on UHF bands.

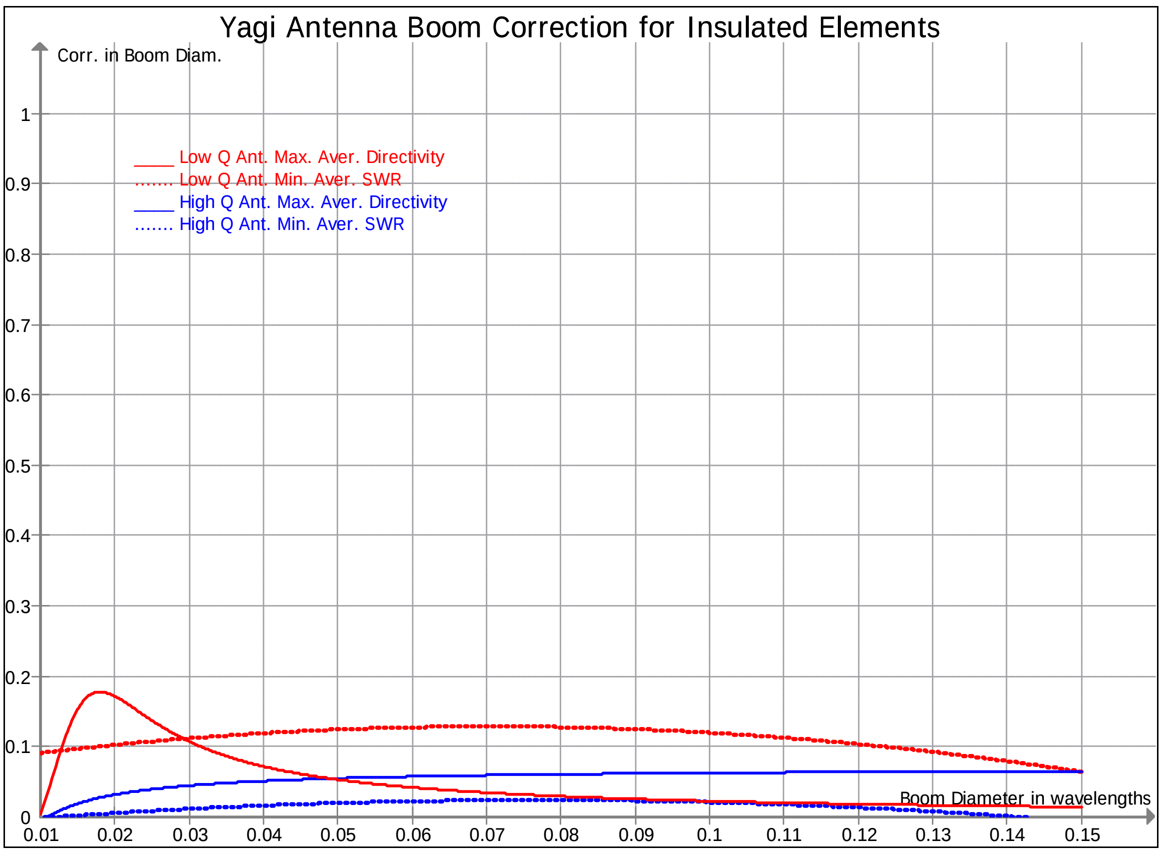

Fig. 6

On **Fig. 6** we can see a diagram with the same axis setting as on **Fig. 4** in order to be easier for comparisons. But this time it is a diagram for antennas with very big boom diameters and with insulated elements that pass through the metal boom. It is obvious that influences and thus compensation values of *boom corrections* are much smaller than for bonded elements. It is interesting to notice that big boom diameter correction for insulated elements also have saturation but at much smaller values as can be seen on diagram on **Fig. 6**.

Conclusion

In this paper we presented summary results of our simulations and analyses of various influences on antenna and its consequences on Yagi antenna for higher frequencies. Influence of various boom diameters as well as various distances and elements' mounting methods to *boom correction* values for optimum antenna input return loss and broadband directivity of six different antenna designs were compared.

It was confirmed once again that antenna design and corresponding Q factor is an important parameter which defines antenna susceptibility to boom effects, but also determines extent of *boom correction* effects. It is evident that *boom correction* of Yagi antenna depends very much on its design and that it is not the same for all types of Yagi antennas.

We can use results summarized in this article as guidelines that we have to follow if we want to design and build good UHF Yagi antennas.

As it is visible from diagrams on **Fig.1** and **Fig. 2** it is a good idea to build a very tolerant UHF Yagi antenna with as thin as possible boom and with as large as possible distance between boom and elements. Perhaps this conclusion doesn't sound very new and unexpected, but probably importance of satisfying these demands becomes now much more obvious if good behavior of a built antenna is our goal.

Antenna design software which cannot consider and account for all boom effects is not a very accurate tool for designing and optimizing of UHF Yagi antennas especially those for higher bands.

If we look at results of all these conducted simulations with different elements' mounting method (isolated on safe distance above boom and not isolated passing through boom) **[1, 2, 3, 4, 5** and **6]** and also influence of collected water or ice on elements **[7],** and finally coax cable feeder influence on antenna performance **[8]**, we can see that every particular antenna follows its own specific behavior under all these different circumstances. It always behaves in very similar way which almost entirely depends on its design and corresponding Q factor value. **-30-**

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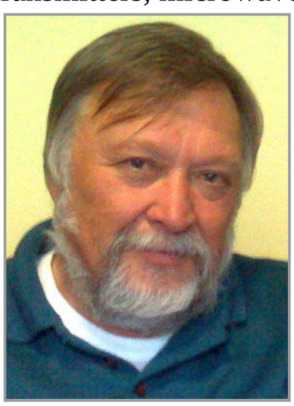
Dragoslav Dobričić, YU1AW, is a retired electronic Engineer and worked for 40 years in Radio Television Belgrade on installing, maintaining and servicing radio and television transmitters, microwave links, TV and FM repeaters and antennas. At the end of his professional career, he mostly worked on various 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.