Yagi Antenna Insulated Elements Boom Correction

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Introduction

The boom of Yagi antenna is an inevitable part of its construction. Theoretically and practically, a Yagi antenna can work fine without a boom. A conducting boom is not an intended radiating part of antenna but only an inevitable part of its support construction.

As we know the Yagi antenna can be built in a few ways. It can be built so that elements are insulated and separated by some safe distance from any conducting boom or so that elements pass through boom. The latter method can be done with elements electrically bonded to the boom and elements electrically insulated from the boom. All of these element mounting methods have their mechanical and electrical advantages and disadvantages plus different boom influences to antenna elements.

So far, in several previous articles **[1, 2, 3, 4]**, we have investigated how the boom dimension, its cross section shape and its distance from antenna elements influence performance of six different 2 m Yagi antennas which are very similar in all characteristics except in Q factor values **[6, 7]**. In these articles we have shown how a boom presence influences Yagi antenna performances when elements are insulated and separated by various distances from a conducting boom and finally how the boom influences Yagi antenna performances when elements pass through a metal boom and they are electrically bonded to it.

In the previous articles **[1, 2]** we showed how a boom influenced elements that were passing through a round and square tube metal boom when they were not insulated from it and what is the difference in performances if we use these two different cross section shapes of boom.

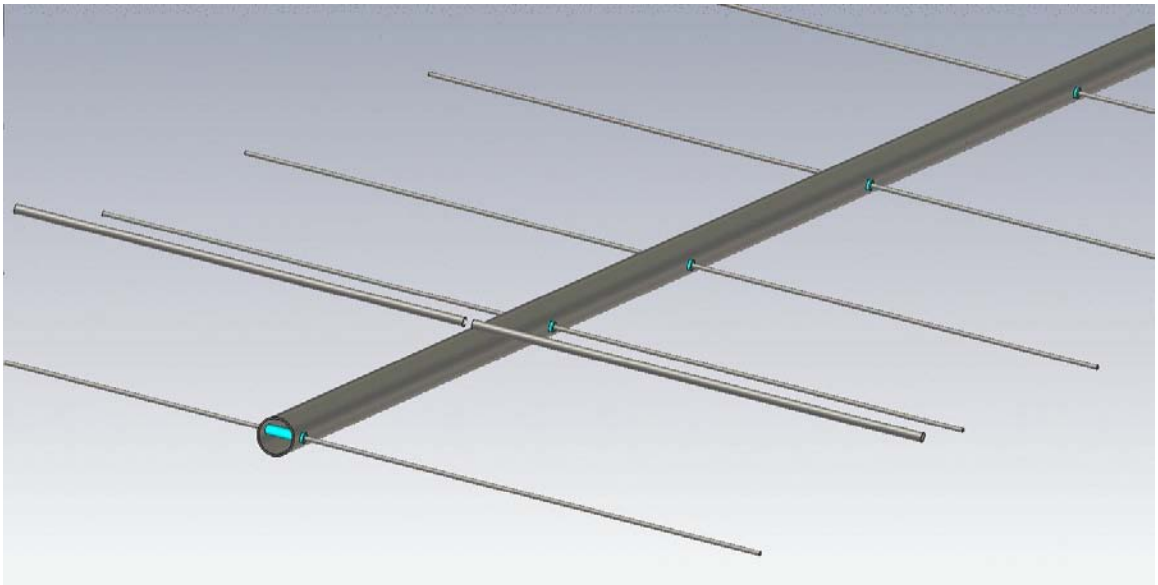


Fig.1 Simulation model of Yagi antenna with insulated elements passing through metal boom and elevated driven element

There is another possible mechanical mounting of Yagi antenna elements on a boom that became very popular and frequently used. This is when elements are passing through a metal boom, but they are electrically insulated from it. Usually, a piece of plastic tube that is slipped onto an element at its center and pulled through the boom provides electrical insulation that reduces interaction between boom and elements and thus magnitude of boom influence on antenna performances (Fig. 1).

As we have seen in our past articles, 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. From the theoretical calculations and practical measurements it is known that the presence of a thick metal 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 to 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.

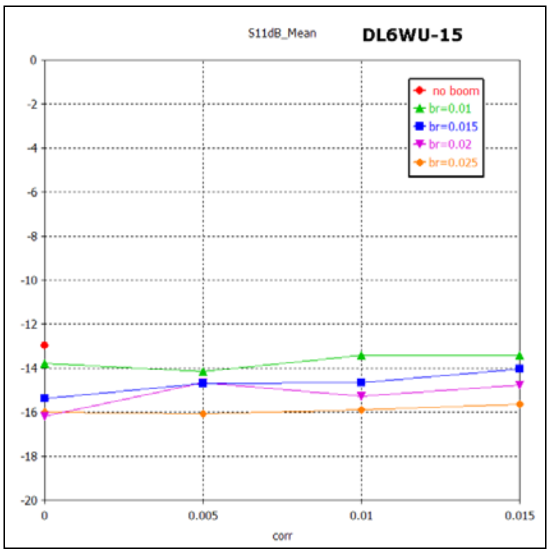
Different Yagi antenna designs show different sensitivity to environmental impacts and it is expected that an antenna boom, as an intruder, can have different effects on different antenna designs as well.

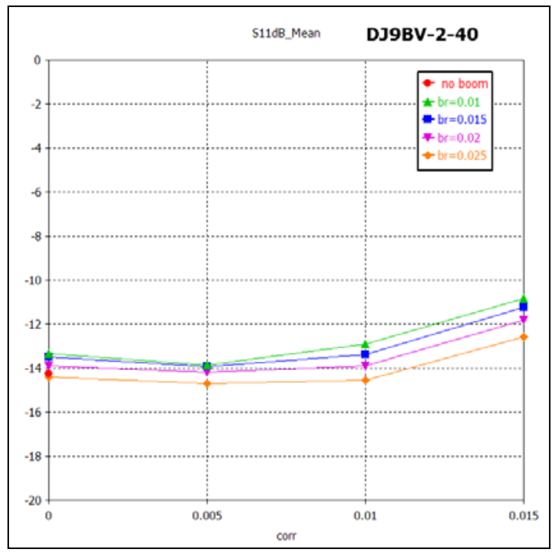
In this investigation we will examine how metal boom influences antenna performance when insulated elements are passing through it.

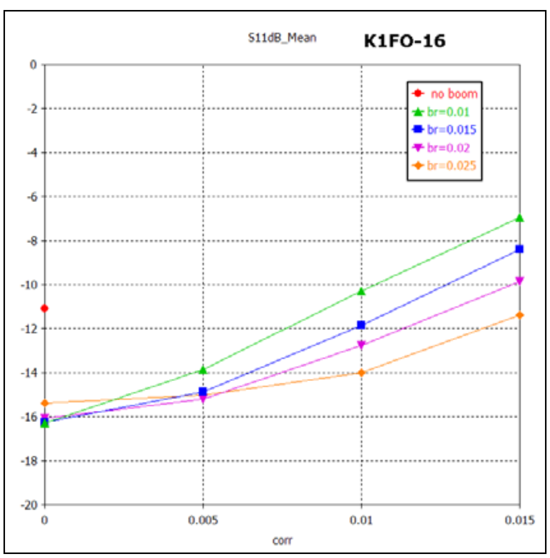
Boom correction

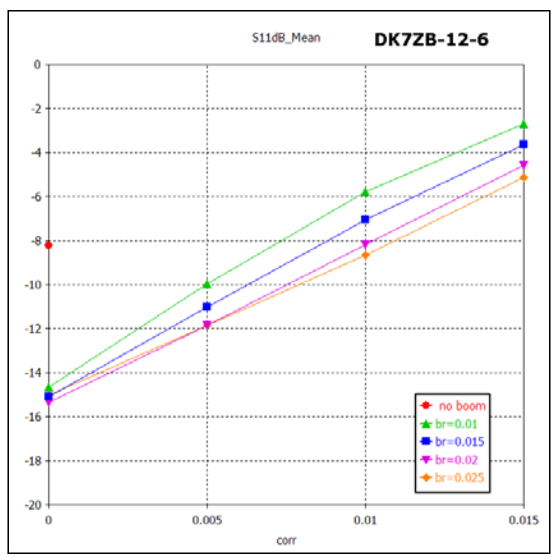
In the case of the performance frequency shift due to boom influence, it is necessary to compensate it for the length of elements to maintain antenna performances on the desired frequency. Element mounting methods, boom diameter and distance between boom and elements determine magnitude of the boom's 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 a previous article we found that this general rule of thumb for *boom correction*, without insulated elements passing through 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 antenna optimum performance.









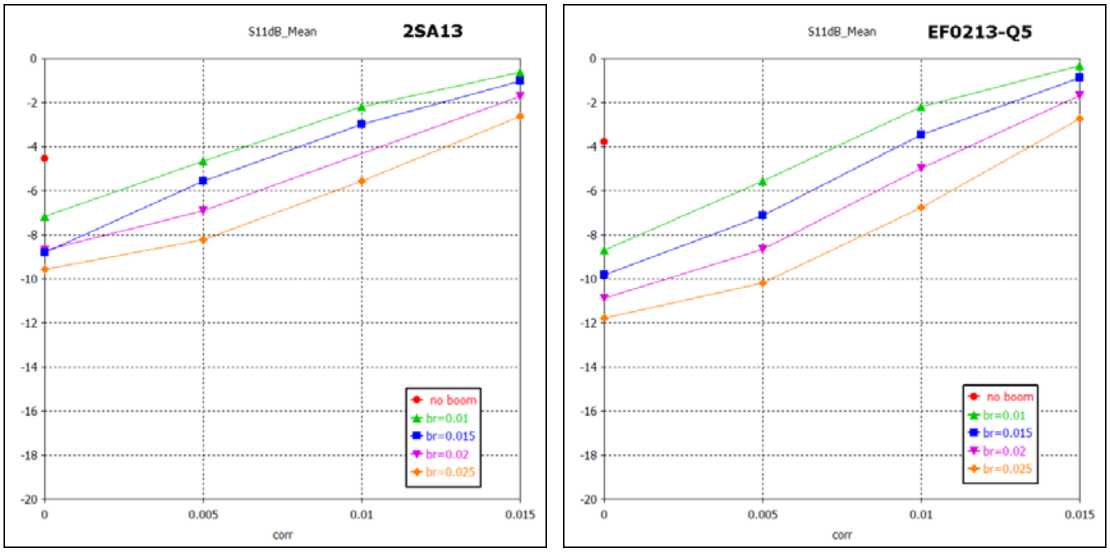


Fig.2 Antenna input return loss mean value in 144…146 MHz band for different boom radius (br) and boom corrections (corr)

For elements passing through the boom but insulated from it, a general rule of thumb for *boom correction* is 15…25 % of boom diameter — for usual boom diameters (20…50 mm) due to lesser interaction between boom and elements. Higher correction percentage is for booms with larger diameter which show a more severe boom influence on the antenna.

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

However, our past simulations show that 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.

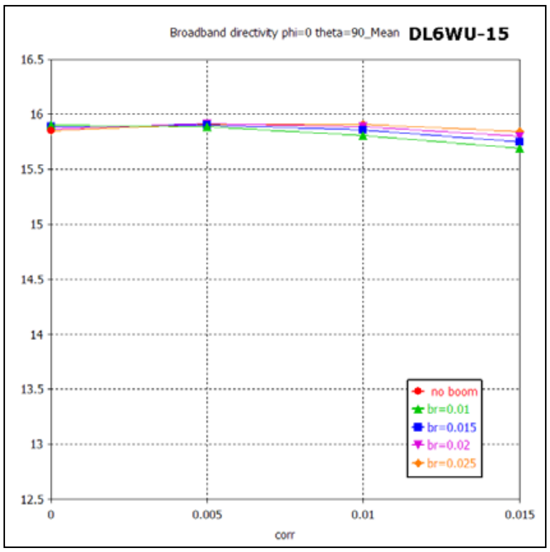
Simulation conditions

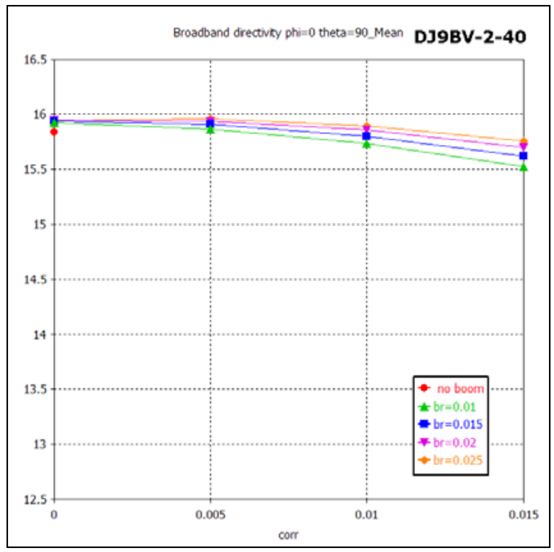
All six Yagi antennas that were used in past articles **[1, 2, 3, 4** and **5]** were simulated again under the same conditions. A variable diameter conductive round tube boom was placed exactly at the axis of antenna so that the elements with slipped plastic tube insulators pass right through the center of round tube boom (Fig. 1). Dielectric permittivity of used plastic is set to be very low and close to 1. Dielectric losses in plastic insulators were not considered in this simulation. Wall thickness of plastic tube insulator is set to be 2 mm. Length of plastic tube insulator is 4 mm longer than boom diameter.

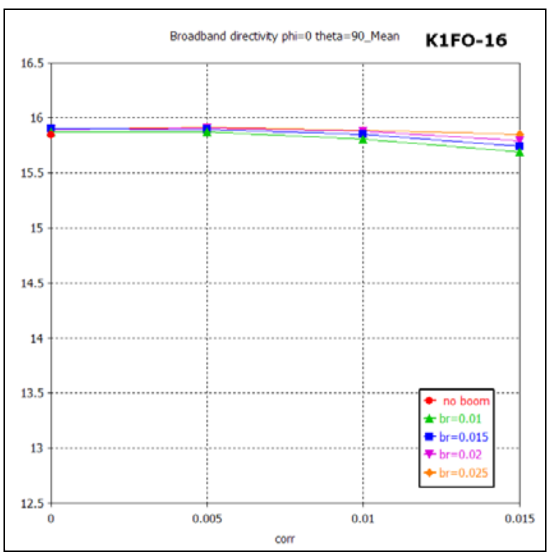
It represents a Yagi antenna simulation with elements that are insulated from a boom using plastic tube slipped over the elements at the middle of the length and mounted so that they are passing through the conductive boom. Simulation conditions were very similar to a practical situation when a single antenna, with conductive round tube boom and insulated elements that are passing through it, is mounted on the top of a very tall and slim pole. As in past simulations, the pole itself is not a part of simulation model.

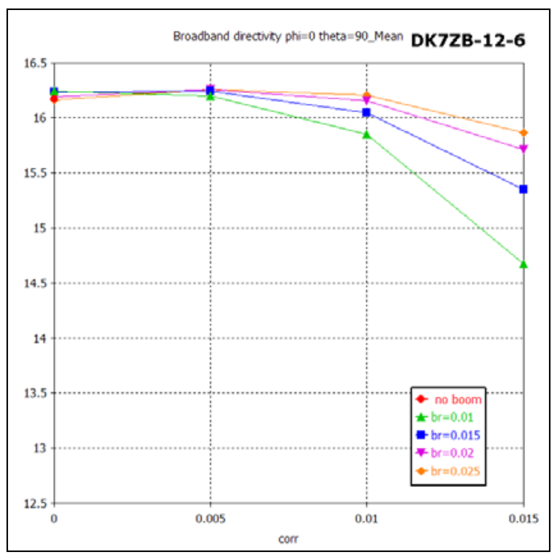
Element lengths have been changed to compensate for boom effects. This lengthening of elements known as *boom correction* was varied from 0 to 15 mm. Correction was applied on all elements except a driven dipole because it is not passing through boom. Driven dipole element axis is elevated above the boom's top most surfaces for about one boom radius. During simulations boom radius was changed from 10 to 25 mm as parameter. As in past simulations the thickness of metal boom tube wall is set to be 2 mm.

For comparison purposes, the metal boom was removed and an antenna without boom and with zero *boom correction* was simulated with the same program's spatial discretization (esoteric software term, see definition at bottom) parameters in order to obtain accurate reference results. These results are designated as "*no boom*" on diagrams.









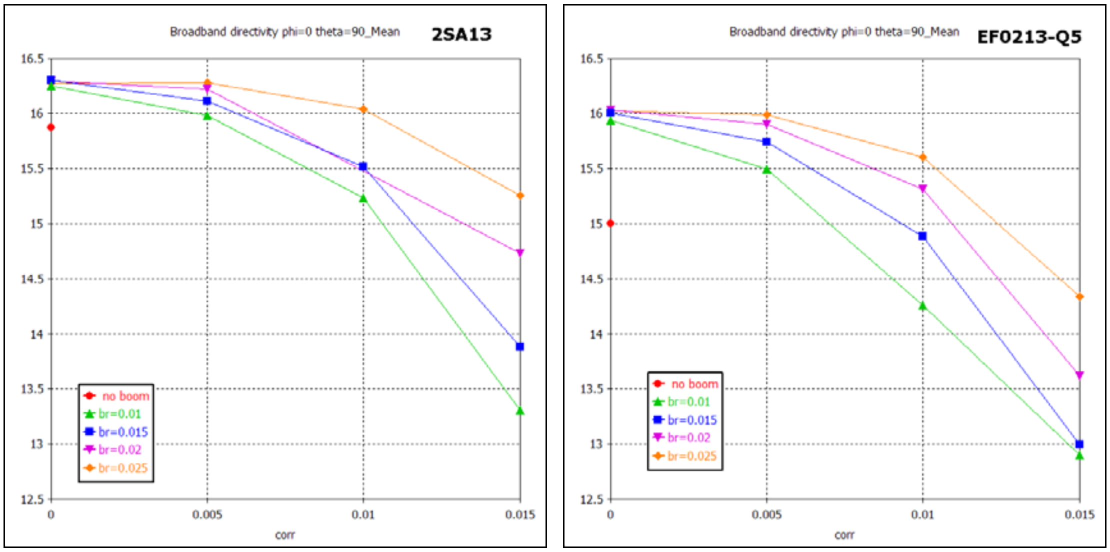


Fig.3 Antenna broadband directivity mean value in 144…146 MHz band for different boom radius (br) and corrections (corr)

For this task the antenna simulation software based on *Finite Integration Technique* has been used once again **[5]**. As in the past articles, metal boom influence has 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* for antennas with insulated elements that are passing through a metal boom and how it changes with different boom radius and antenna designs.

Input Return Loss

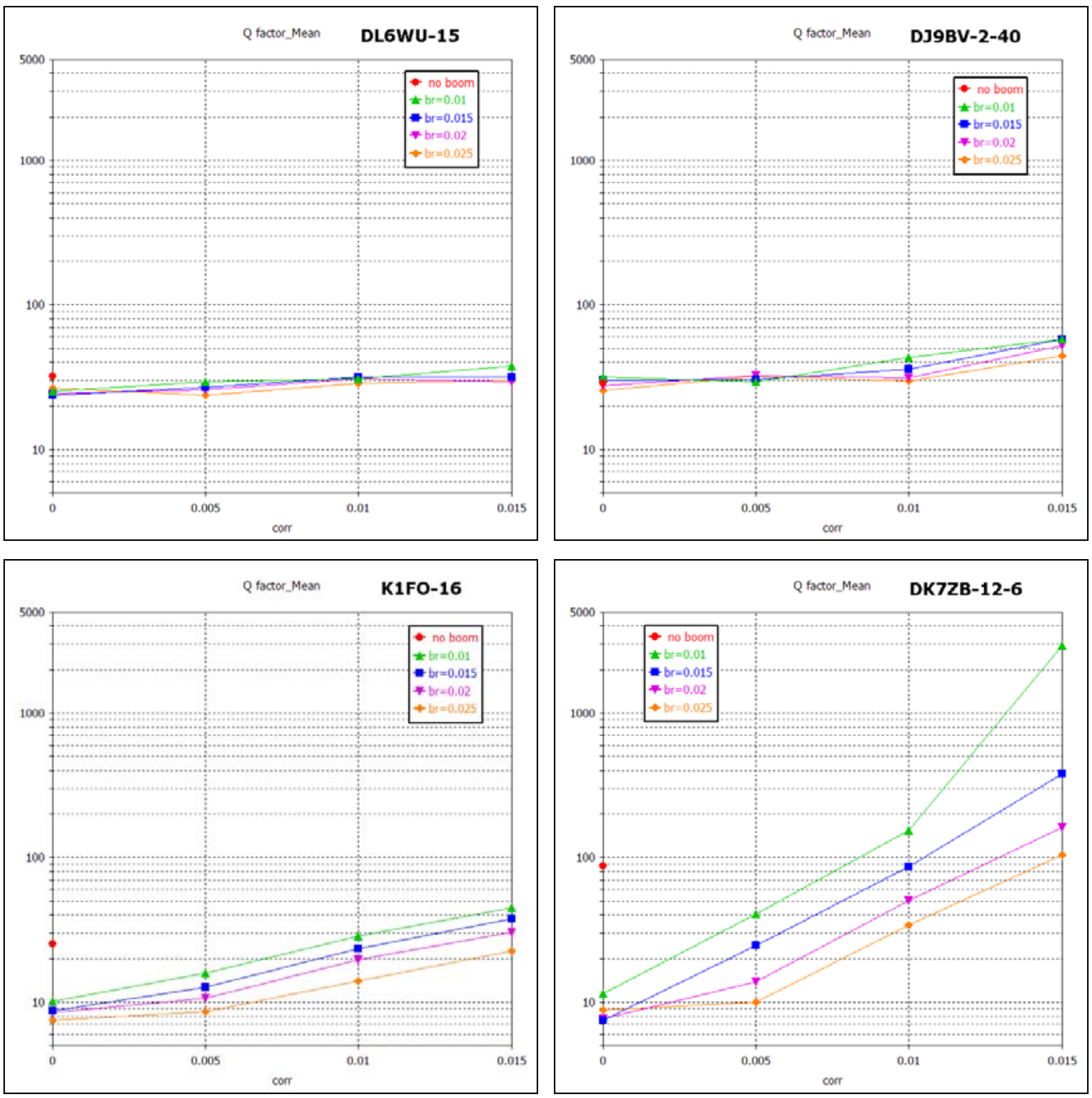
The presented diagrams on Fig. 2 show input return loss mean value dependence of applied *boom correction* for various boom diameters. We can see that only DL6WU and DJ9BV antennas are almost completely independent on applied *boom corrections* and retained good input return loss for all boom diameters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

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

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

From results in Fig. 2, 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 diameter and applied *boom correction* in 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.

If we compare these results with similar diagrams from previous article **[2]** for antennas without insulated elements we can see that the antenna input return loss has similar behavior but that the boom impact magnitude on insulated elements is smaller. As a result of this lesser boom influence, overall variation of input return loss is also noticeable smaller.



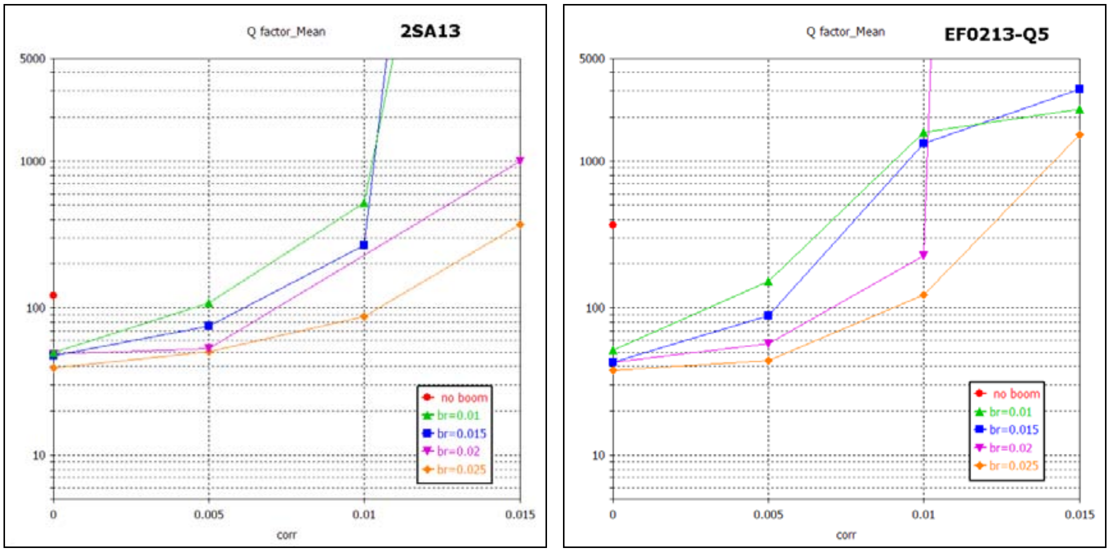


Fig.4 Antenna Q factor mean value in 144…146 MHz band for different boom radius (br) and corrections (corr)

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 were compensated with wrong *boom correction* for used boom diameter, or even not compensated at all.

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

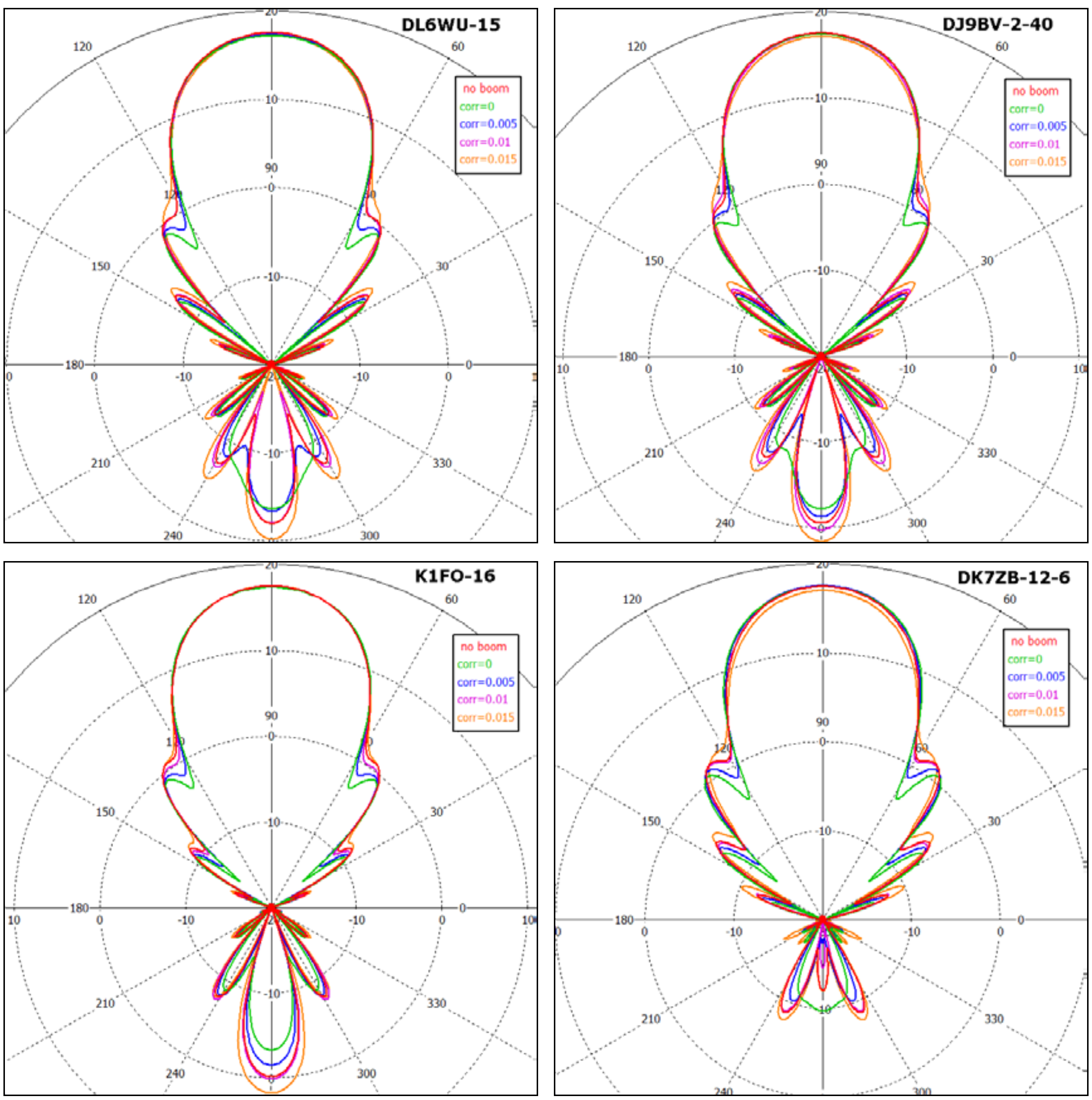
Similar as in our past simulations, EF0213-Q5 antenna shows directivity close to three low Q factor antennas but with very big changes of performances for different boom diameters and applied *boom corrections*. For this antenna *boom correction* value also appeared that has to be less than for low Q factor antennas and very critical.

Diagrams in 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

As we mentioned in our previous articles, 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 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 most delicate measure of antenna stability and in accordance with this value it was possible to make very probable predictions how some antennas will behave under various environmental influences **[6, 7]**. This fact was confirmed many times in almost all our past simulations of antennas under various environmental influences **[1, 2, 3, 4** and **6]**.

According to results of many simulations of different antennas under many different environmental attacks it is noticeable that it is not enough that antenna initially has low Q factor value under idealized simulated environmental conditions to be considered a good tolerant antenna. It is necessary to let an 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 between obtained initial Q factor value in idealized simulated conditions and Q factor value under some serious environmental attack **[6]**.



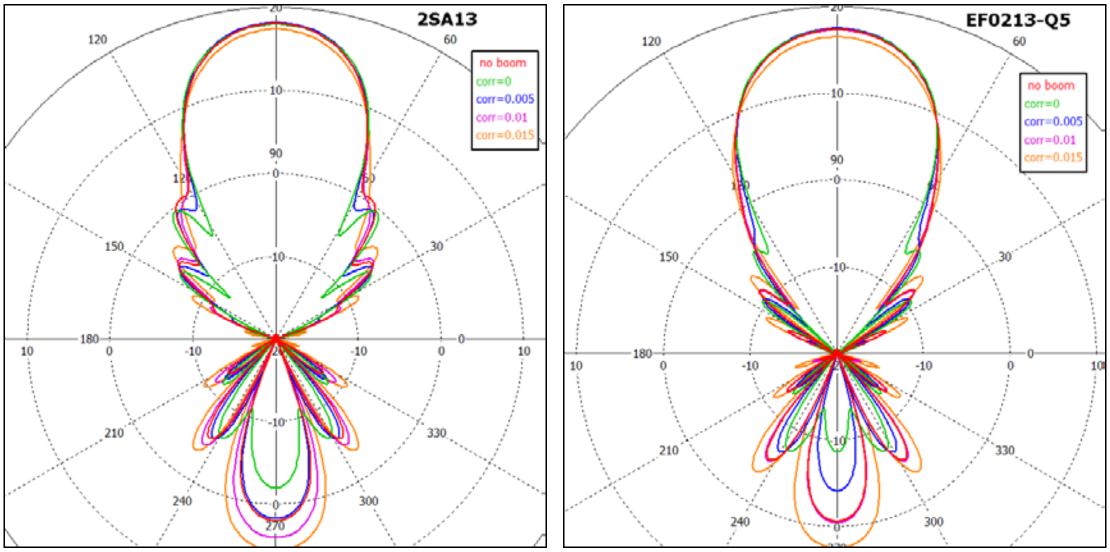


Fig.5 Radiation diagrams in E plane for br=15 mm at 144.5 MHz for all six antennas in dependence on boom correction

Presented results in this article confirmed this fact once again. In this investigation antennas that show very stable and low Q factor mean value showed also very tolerant behavior preserving good input return loss and stable high directivity mean value under all circumstances.

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 curve only when 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.

Antenna pattern

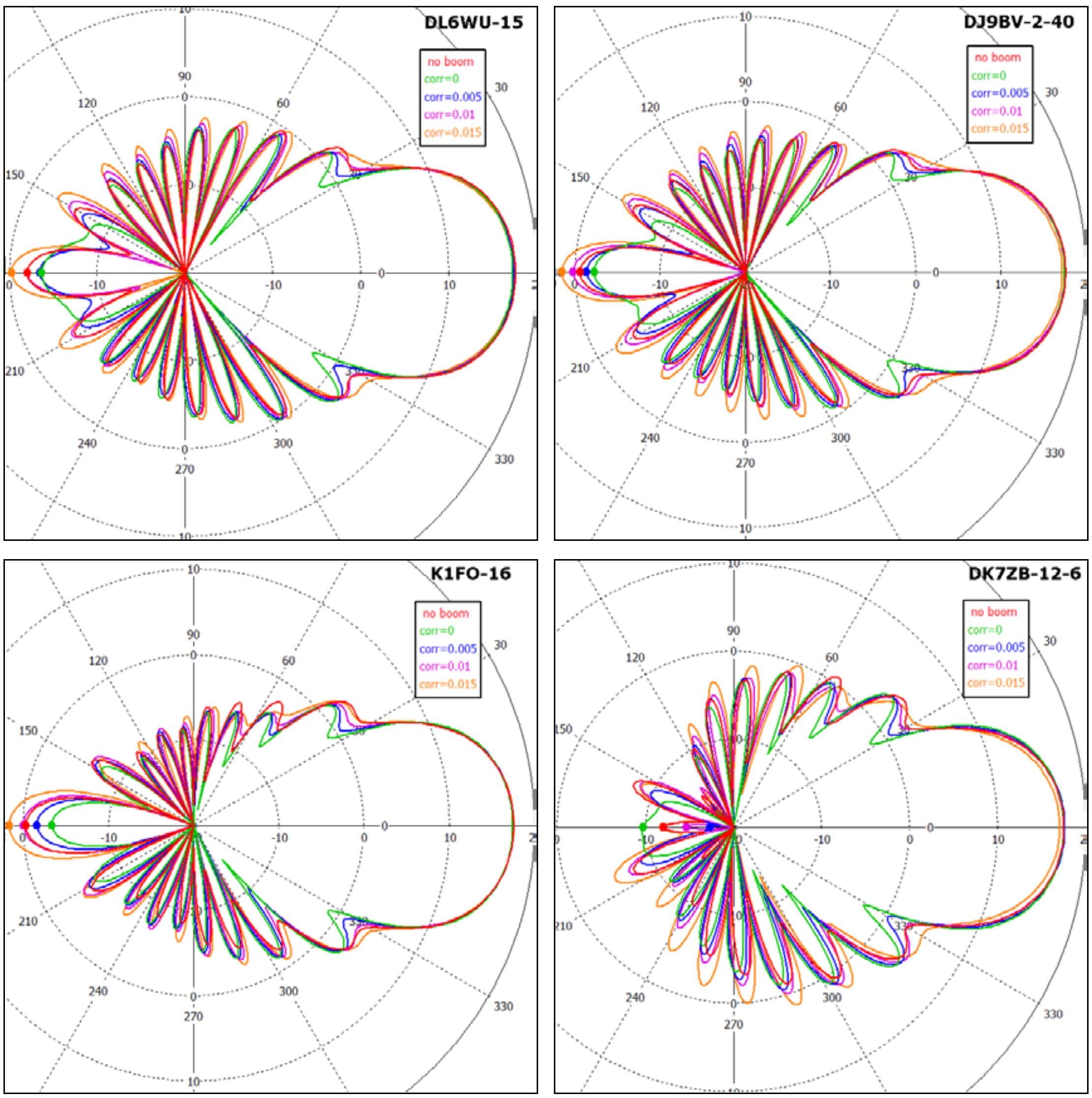
All antenna patterns were taken on frequency 144.5 MHz. Because of limited article length it was not possible to publish radiation patterns of all six antennas for all simulated boom radiuses. But as illustration of each particular antenna behavior with various *boom corrections* we decided to publish only patterns for boom radius of 15 mm (30 mm diameter) which is most frequently used for this antenna length.

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 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.

Without insulated elements mounted through metal boom we have the highest possible interaction between boom and elements. As we saw in our two previous articles **[1, 2],** 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!

With elements that are passing insulated through boom all these influences are not so big. The size of boom influence is less due to elements' insulation from boom, and consequently magnitudes of monitored parameters changing are also smaller. 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 magnitude of environmental impact also depends on its construction, i.e., its element mounting methods.



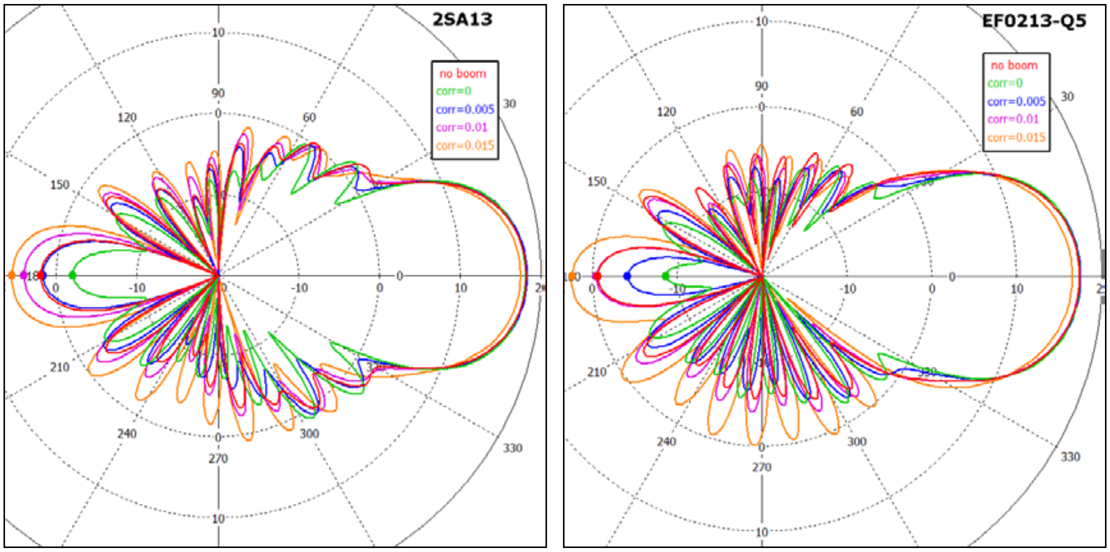


Fig.6 Radiation diagrams in H plane for br=15 mm at 144.5 MHz for all six antennas in dependence on boom correction

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 Boom Radius [mm]				
	Parameter	**10**	**15**	**20**	**25**
DL6WU-15	S11	0-15	0-15	0-15	0-15
	BD	0-15	0-15	0-15	0-15
	Q	0-15	0-15	0-15	0-15
	common	**0-15**	**0-15**	**0-15**	**0-15**
DJ9BV-2-40	S11	0-15	0-15	0-15	0-15
	BD	0-15	0-15	0-15	0-15
	Q	0-15	0-15	0-10	0-15
	common	**0-15**	**0-15**	**0-15**	**0-15**
K1FO-16	S11	0-10	0-15	0-15	0-15
	BD	0-15	0-15	0-15	0-15
	Q	0-15	0-15	0-15	0-15
	common	**0-10**	**0-15**	**0-15**	**0-15**
DK7ZB-12-6	S11	0-5	0-5	0-10	0-10
	BD	0-10	0-15	0-15	0-15
	Q	0-5	0-5	0-10	0-10
	common	**0-5**	**0-5**	**0-10**	**0-10**
2SA13	S11	0	0	0	0-5
	BD	0-5	0-10	0-10	0-10

	Q	0	0	0-5	0-5
	common	**0**	**0**	**0**	**0-5**
EF0213-Q5	S11	0	0	0-5	0-5
	BD	0-5	0-10	0-10	0-10
	Q	0	0-5	0-5	0-5
	common	**0**	**0**	**0-5**	**0-5**

Criterions for the optimum *boom correction* in Table 1 have been chosen so that narrow bandwidth antennas can meet them too. Criterions were as follows:

(i) Antenna input return loss should be better than -10 dB (approx. SWR= 2) at least in frequency band 144…145 MHz, **or** better than -6 dB (approx. SWR= 3) in 144…145.5 MHz frequency band.
(ii) Broadband directivity should not fall more than 0.5 dB from maximum value at least in 144…145 MHz frequency band, **or** no more than 1 dB in 144…145.5 MHz frequency band.
(iii) Antenna Q factor should not rise to value more than 50 at least in the 144…145 MHz frequency band, **or** no more than 100 in 144…145.5 MHz frequency band.

However, even besides such easy criterions some of high Q antennas hardly satisfied them!

Conclusion
In this paper we presented simulations and analyses of various radius conductive boom influence on antenna when elements are insulated from boom and passing trough it.

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.

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 it is not the same for all types of Yagi antennas.

From the results summarized in Table 1 it is obvious that for low Q antennas, with elements passing through the boom and electrically insulated from it, a “general rule of thumb” correction of about 15…25 % of boom diameter is quite accurate. Antennas designed by DL6WU, DJ9BV and K1FO follow this rule with very good accuracy and even more, they are optimized in much wider band of boom correction values. 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! They very easily meet optimum boom correction criterion requirements used in Table 1.

As it is visible from the diagram in Fig.3 they also kept the same average directivity for all different boom diameters and boom corrections as without boom. DK7ZB antenna kept the same average directivity with and without boom only when it is exactly corrected for optimum directivity performance for used antenna boom diameter. 2SA13 and EF0213-Q5 antennas show lower average directivity without boom than with boom because metal boom presence lowers its Q factor and broadens its broadband directivity and working bandwidth.

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 some high Q antennas most often gives suboptimal antenna performance compensation. These antennas generally meet optimum boom correction requirements used in Table 1 with much more difficulty, and some of them hardly satisfied minimum needed criterion values even though the criteria were trimmed to make possible for narrow band antennas to pass.

If we compare results of this simulation with results of previously conducted simulations with different elements mounting (isolated at safe distance above boom and not isolated passing through boom) **[1, 2, 3,** and **4]** and also influence of collected water or ice on elements **[6]** we can see that every particular antenna follows its specific behavior under all of this different circumstances. It always behaves in very similar way which almost entirely depends on its design, i.e. Q factor.

References:

1. Dragoslav Dobričić, YU1AW, **Yagi Antenna Elements Correction for Square Boom**, *antenneX*, January 2010, Issue No. 153.
2. Dragoslav Dobričić, YU1AW, **Yagi Antenna Elements Boom Correction**, *antenneX*, December 2009, Issue No. 152.
3. Dragoslav Dobričić, YU1AW, **Boom Distance Influence on Yagi Antenna**, *antenneX*, August 2009, Issue No. 148.
4. Dragoslav Dobričić, YU1AW, **Boom Radius Influence on Yagi Antenna**, *antenneX*, June 2009, Issue No. 146.
5. Dragoslav Dobričić, YU1AW, **Boom Influence on Yagi Antenna**, *antenneX*, May 2009, Issue No. 145.
6. Dragoslav Dobričić, YU1AW, **Yagi Antenna Design Sensitivity in Practice**, *antenneX*, November 2008, Issue No. 139.
7. Dragoslav Dobričić, YU1AW, **Yagi Antenna Q factor**, *antenneX*, July 2008, Issue No. 135.

Discretization

A software term meaning this is mesh generating, or dividing solids to cells, or dividing solids to discrete parts, or discrete pieces. This makes possible to calculate currents in every cell as it is separated from other cells. It is quite analogous to segmentation in NEC software. The difference is that segments in NEC are always one-dimensional but cells, or mesh, or discrete parts, can be two or three dimensional depending of used solver.

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

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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.