Coaxial Cable Feeder Influence on Four Stacked Yagi Antennas Array

Dragoslav Dobričić, YU1AW
dragan@antennex.com

Introduction

A previous article series consisted of two parts **[1, 2]** showing the results of investigating how a coaxial cable antenna feeder influences antenna performance in a situation when minimum and full interaction between antenna and cable is achieved**.** Investigations were conducted by computer simulations of six different antennas under the same conditions.
In the first part of the previous series, results show a high degree of dependence on cable approaching angle *alpha* to antenna driven element. This happened despite that the approaching angle *alpha* was always kept lying in the antenna symmetry plane in order to maintain minimum interaction between cable and antenna. Even under these idealized conditions and in the absence of any other environmental effects, results show considerable antenna performance degradation for some antennas.

In situations when we use a horizontally stacked antenna array, it is simply not possible to have the cable lying in the vertical plane of antenna symmetry. In the second part of the article series, we presented results of investigations conducted on how coaxial cable influences antenna performance when it is not lying in antenna symmetry plane. It is usually used for feeding two horizontally stacked antennas or four antennas stacked two over two, or due to any other reason depending on mechanical support construction demands. In this situation, the cable cannot lie in the antenna symmetry plane, and it is approaching a Yagi antenna's driver element under some angle *beta* which is lying in the plane perpendicular to the antenna symmetry plane. In such case, cancelations of some effects were present in a lesser degree and we got more influence than in a situation when the cable was lying exactly in the antenna symmetry plane. In this situation it was also noticeable that coaxial cable became a significant part of the antenna's radiating structure. Due to significant coaxial cable influence and radiation, antenna radiation diagrams in both planes were considerably distorted.

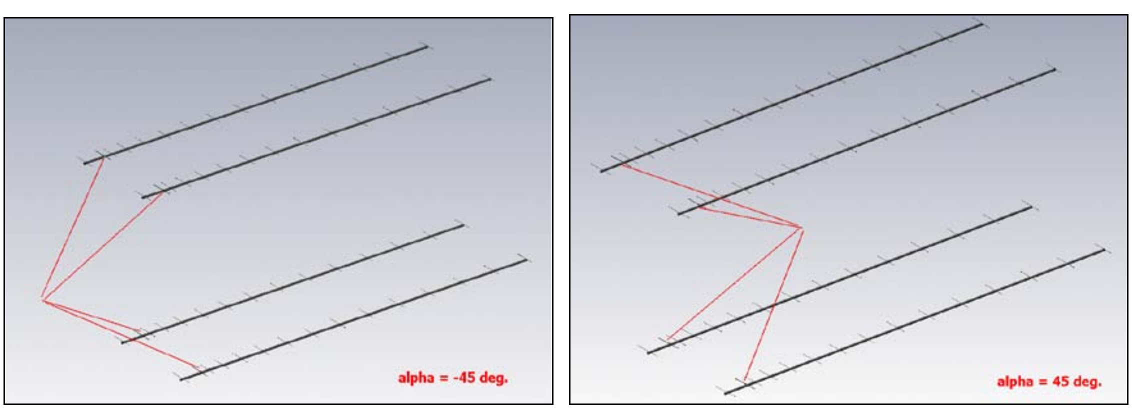


Fig.1 Yagi antenna array with coaxial cable in pyramidal form with backward (left) and forward (right) orientation

In this article we will present results of an investigation on how coaxial cable feeder influences four Yagi antennas stacked in an array two over two when cables are arranged in a few different ways.

In the case of four stacked antennas, feeding cables usually form a letter X with 1:4 power divider placed in the crossing center. Common plane, in which these cables form a letter X and power divider lays, can be the same plane in which also all Yagi antenna active dipole elements lay. If feeding lines form such symmetrical pattern which is lying in one common plane then we can expect cancelation of some influences of cable to antenna array pattern. But very often, power divider can be moved forwards or backwards from that common plane depending on other mechanical support construction demands, and in this case cables form a pyramidal shape with power divider at pyramid's tip. In such cases cancelation of effects could be different and we could expect a different amount of influence.

From the previous investigation results given in past articles, which show that least influence between antenna and cable occurred if the cable is tight to the boom and support structure, we decided to make investigation of antenna array with coaxial cable formed in a letter H as given on Fig. 2-right. This is, besides the forward oriented pyramidal form given on Fig. 1-right, most frequently used way of four antenna array feeding. With this way of feeding it is possible to mount usually heavy power divider on support structure, and thus satisfy one of important mechanical demands. Cables formed in a letter X are also quite common when cables are soldered directly without using bulky and heavy power divider with impedance transformation capabilities. Backward pyramidal form is relatively uncommon although it gives some benefits in performances, but it is much more complicated from mechanical point of view and also it makes overall antenna array bulkier.

In Fig. 1 and 2 we can see simulation models of antenna arrays of four stacked Yagi antennas, i.e., two vertically stacked bays of two horizontally stacked antennas with coaxial cable feeder that is arranged in a few different ways.

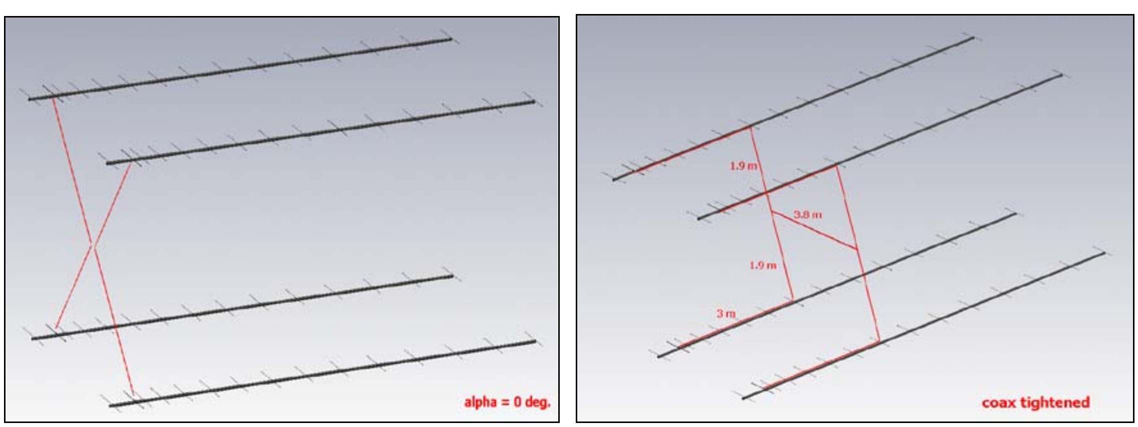


Fig.2 Yagi antenna array with coaxial cable formed to lay in one plane shaped as letter X (left) and as letter H tighten to boom and antenna support construction (right).

Simulation conditions
All six Yagi antenna arrays were simulated under the same conditions. A 50 mm diameter conductive round tube boom was placed below the elements so that the distance between the boom axis and elements axis was 40 mm. It represents a Yagi antenna simulation with elements insulated from a boom and mounted on the boom using plastic insulators with very low dielectric permittivity and with fixed 15 mm height of element axis above the boom's most top surface. Each Yagi antenna in array, with elements set in the horizontal plane, was fed by a fixed diameter coaxial cable that was coming from the common power divider to the driven element in a few different cable arrangements.

Angle *alpha* is the same as it was defined in previous article and it is lying in the symmetry plane of the antenna. Angle *beta* which is lying in the plane perpendicular to the boom axis is also defined in the same way as in the previous article. By setting various values for these two angles and cable length, it was possible to change the cable position and form different cable feeding arrangements.

As in the previous analysis, coaxial feeder is of 10 mm diameter and it ends in the vicinity of the boom's most bottom surface, but doesn't touch it. Both ends of outer conductor of the coaxial cable are left unconnected. The RF source was placed and connected to the dipole arms at the dipole center insulation gaps. This represents a simulation of four Yagi antennas stacked in array fed with coaxial cable over ideal 1:1 balun which represents infinite impedance to common mode currents flowing on the outer surface of the coaxial cable. This setup gives a good opportunity to investigate coaxial cable influence on the Yagi antenna array only due to induced currents which flow on a cable's outer surface as a consequence of an antenna's near field.

Simulation conditions were very similar to a practical situation when an array of four stacked Yagi antennas is mounted on the top of a very tall and slim pole that is not part of the antenna simulation model. Antenna stacking distance is 3.8 m in both planes and that is close to optimum stacking distance for antenna boom length of about 4 wavelengths and obtained directivity of investigated antennas.

A few different situations were simulated. The first was when the coaxial cable was approaching each antenna from directions of the common power divider that was lying in the center between antennas in the same plane with cables and antenna active dipoles and thus forming letter X shape. The second was when previous arrangement was changed because power divider did not lay in common plane of antenna active dipoles and cables. In this situation we can have two possible places for power divider: one in front of the common plane and another behind it. In both possible cases, cables formed pyramidal shape, but first with the pyramid's tip oriented forwards and in the second case backwards in regard to the antenna's main beam direction. Finally, it is possible to keep the cable close to the boom and antenna support structure which form letter H and lay in plane which is perpendicular to antenna booms and it is shifted ahead around 1.5 wavelengths from the plane where antenna active dipoles lay.

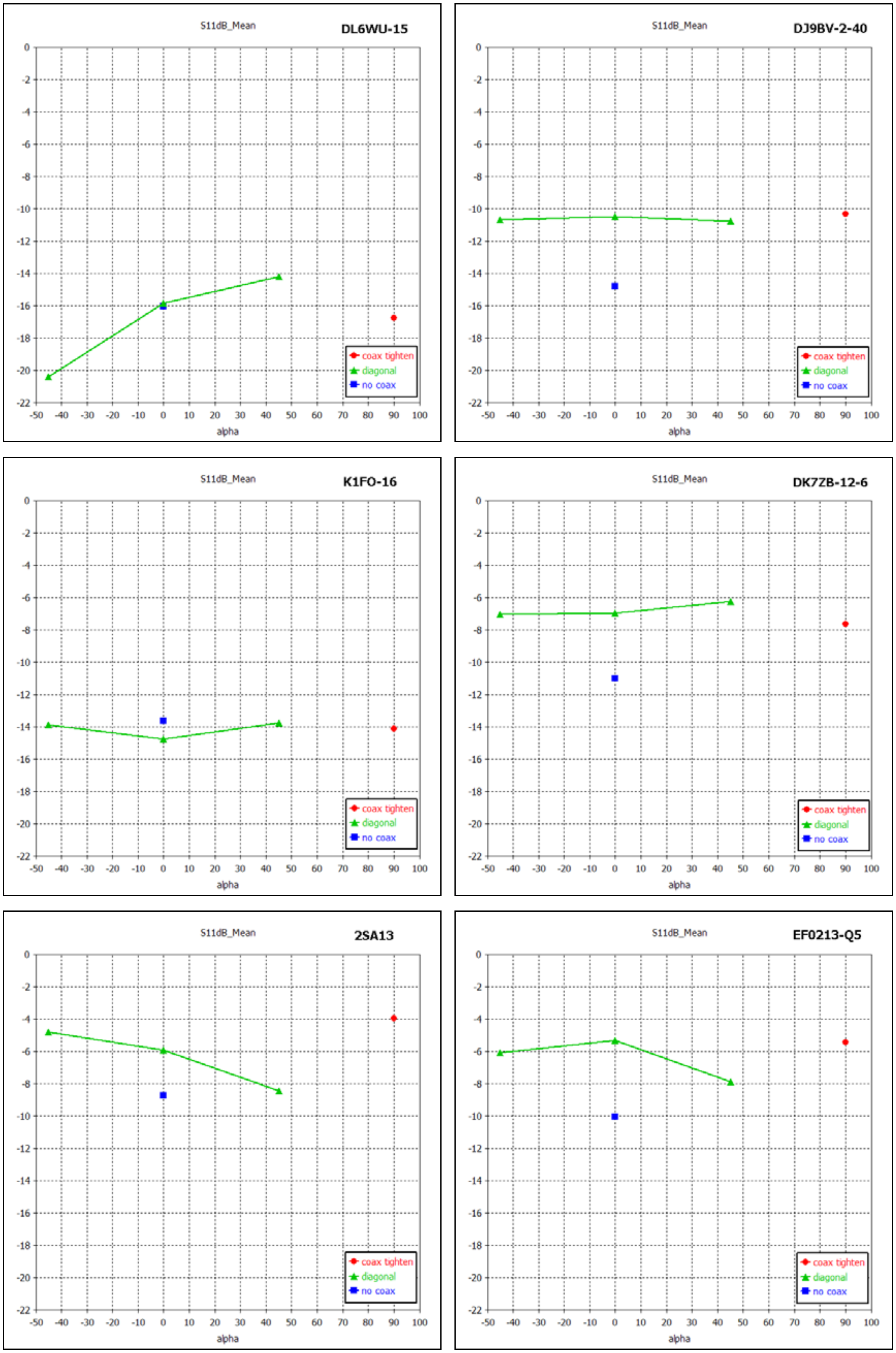


Fig.3 Antenna input return loss mean value in 144…146 MHz band for different cable arrangements and antennas

This simulation, together with previous ones, should give an answer to the question what would be the best way to guide coaxial cable in regard to antenna boom and other possible support structures, and how much various antennas are sensitive to this.

For this task the antenna simulation software based on FIT method has been used once again, instead of the usual MoM based software which has already been found inadequate due to some unacceptable program limitations **[3].** Similarly as in the previous articles, coaxial cable 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 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

On the presented diagrams the label ***"diagonal"*** with angle alpha = -45 deg. corresponds to backwards oriented pyramidal form of feeding cables (Fig. 1-left), alpha = 0 deg. corresponds to letter X shaped cables (Fig. 2-left) and alpha = 45 deg. corresponds to forwards oriented tip of pyramidal feeding cables form (Fig. 1-right). The label ***"coax tighten"****-ed* corresponds to letter H shaped cables that are tightened to boom and antenna H-frame support structure (Fig. 2-right), while label ***"no coax"*** means that only four antennas with booms but without any feeding coax cable were simulated for comparison purposes. In NEC and other MoM programs single antennas and stacked antenna arrays are usually simulated without booms and without cables. Because of that they give much idealized results and antenna directivity patterns. It is usually so because these programs cannot accurately simulate booms and cables in the vicinity of the antenna due to well known and documented program limitations **[3]**.

Influence on input return loss

Some higher degree of coaxial cable influence on antenna input return loss and SWR was expected because of the cable position that does not produce the minimum of interaction between antenna and cable as in the first part of previous article **[2]**. Conducted simulations gave clear confirmation that the presence and position of coaxial cable feeder that is out of antenna symmetry plane produces considerably more change of antenna input impedance and input return loss mean value. But there is a big difference between particular coaxial cable arrangements and antenna designs.

DL6WU and K1FO antenna arrays show that they are very tolerant on cable arrangements. In all of the used arrangements they do not show almost any degradation of input return loss mean value comparing to same antenna array simulated without coaxial cable as a reference (Fig. 3). This is the result of their wideband input match and input return loss curves frequency shifting due to cable influence not producing almost any change of input return loss mean value.

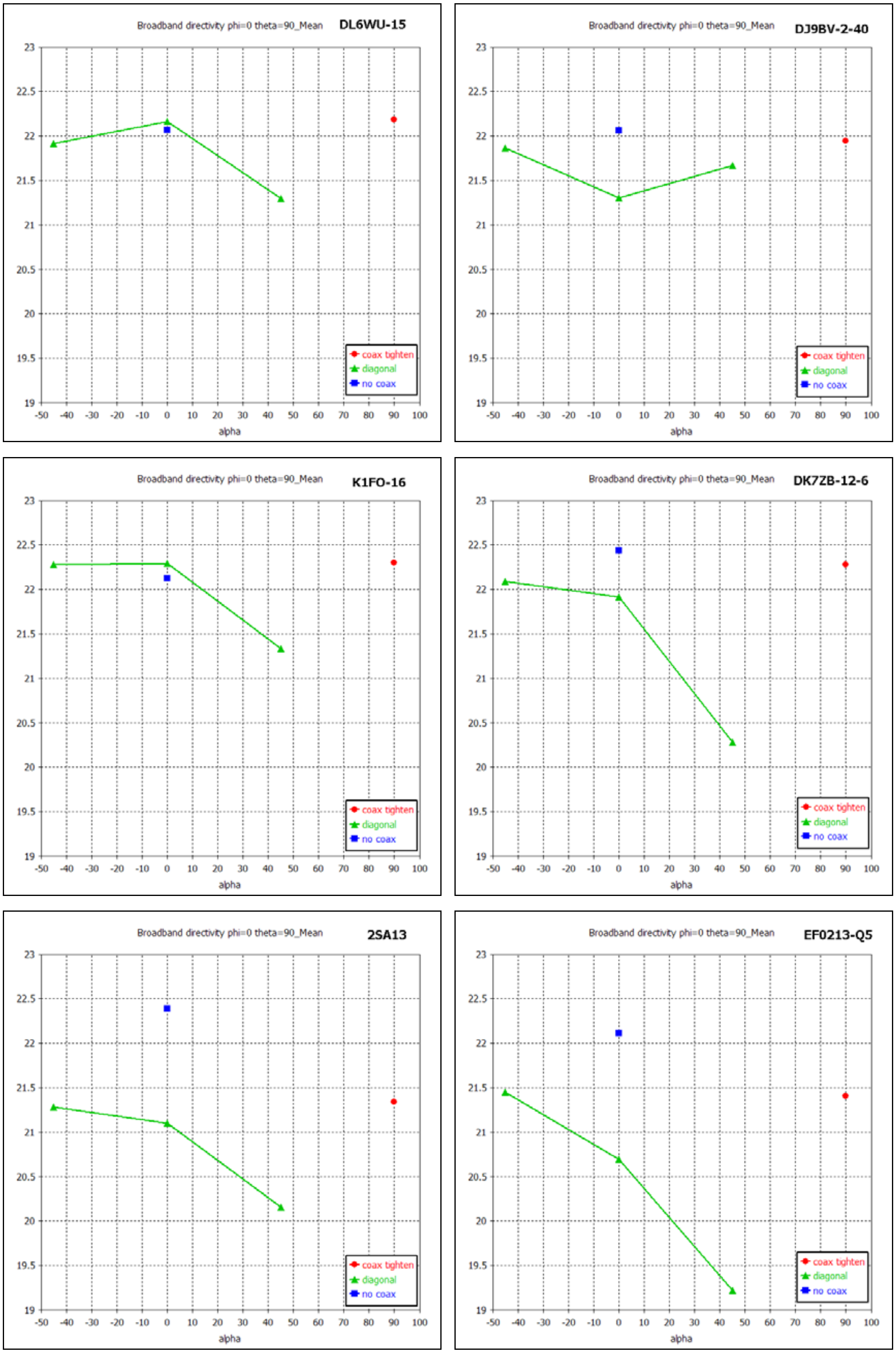


Fig.4 Antenna broadband directivity mean value in 144…146 MHz band for different cable arrangements and antennas

All other antenna arrays show some degree of degradation of input return loss, due to coax cable influence on antennas with all cable arrangements compared to “no coax” reference. Lower Q factor antennas again show better behavior and much less sensitivity to coax cable influence.

It is very interesting that for almost all antennas there is no simple and obvious correlation between input return loss degradation and antenna directivity or gain degradation. This means that we **cannot** easily and intuitively draw conclusions about degree of directivity degradation on the basis of input return loss or SWR degradation!

Influence on broadband directivity

As we mentioned in previous articles **[1, 2]**, antenna broadband directivity curves are being shifted in the frequency domain due to coaxial cable influence similarly as due to a conductive boom or moist influence **[3, 4]**. Higher Q antennas have narrower broadband directivity curves and, due to higher sensitivity to environmental impacts, their directivity curves shift more. As a result, they have considerably higher variation of antenna directivity mean value within the amateur band.

Antenna arrays with DL6WU and K1FO antennas have almost no antenna directivity degradation for “coax tightened” and “diagonal” arrangement with alpha = -45 and alpha = 0 deg. DJ9BV and DK7ZB antenna arrays have very small antenna directivity degradation with “coax tightened” arrangement compared to “no coax” reference. Therefore, all antennas except 2SA13 and EF0213-Q5 with “coax tightened” arrangement achieve almost the same antenna directivity mean value as with “no coax” reference (Fig. 4).

The most severe degradation for all antenna arrays and especially for higher Q antennas is when the cable comes from the forward side of the antenna (alpha = 45 deg.), except perhaps DJ9BV antenna which has a little more degradation with alpha = 0 deg. Unfortunately, this is a very frequently used cable arrangement because it gives some mechanical advantages in power divider mounting.

Influence on antenna Q factor

Changes of antenna Q factor mean value with various cable positions also follow the same rule as for input return loss and broadband antenna directivity. Individual antennas with a higher Q factor suffer a much bigger Q factor change due to cable presence and position than antennas with lower Q factor. This is very similar to change of antenna Q factor due to moist influence or any other environmental effect as we already found and reported in past articles **[4, 5]**.

But here it is also noticeable that coaxial cable becomes a significant part of the antenna’s radiating structure. Besides the changing of radiation pattern, cable presence and radiation also changes antenna input impedance among other things by changing radiation and loss resistance. All these factors together change the Q factor of the individual antenna and of the array too.

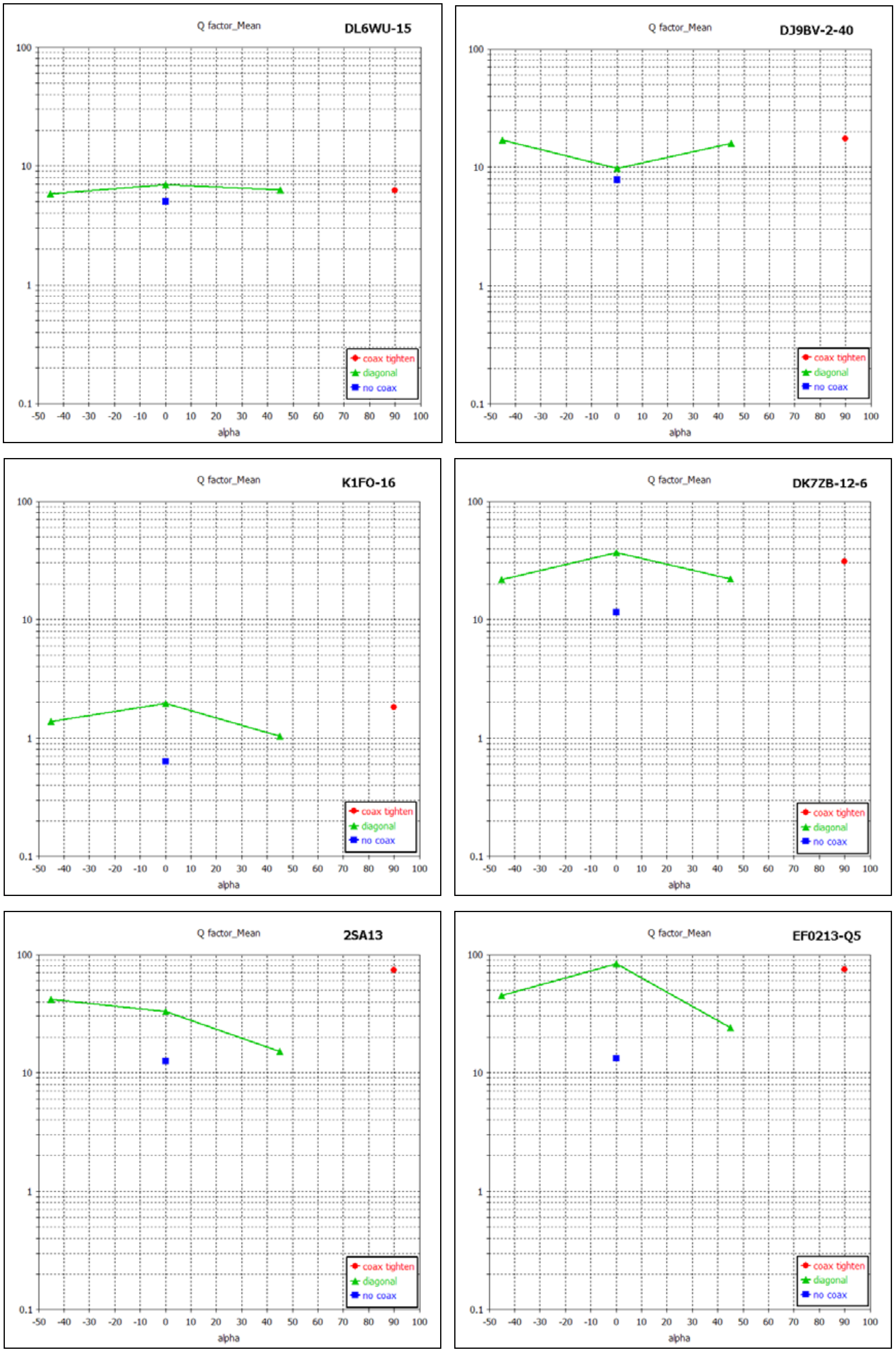


Fig.5 Antenna Q factor mean value in 144…146 MHz band for different cable arrangements and antennas

Antenna arrays consisted of DL6WU, K1FO, DJ9BV and, to a certain degree, of DK7ZB antennas kept its Q factors at low values under all coax cable arrangements compared to "no coax" reference. Other two antennas, 2SA13 and EF0213-Q5, increased their Q factors about 2-5 times from "no coax" reference (Fig. 5). Perhaps it is most interesting that both antennas have very high Q factor with "coax tightened" cable arrangement which is very often used in practice. It is also interesting that high Q antennas stacked in array, but without coax cables, have lower Q factor than an individual antenna has.

Influence on antenna directivity pattern

Radiation diagrams in E and H planes for all six antenna arrays with dependence on cable arrangements are given on Fig. 6 and Fig. 7.

Due to significant coaxial cable influence and radiation for some cable arrangements, antenna radiation diagrams in both planes are considerably distorted. The "cable tightened" arrangement generally shows the least distortion compared to "no coax" reference. But it is obvious that, as it was observed and noticed in a previous article, each antenna has some cable arrangement which is its "Achilles' heel" and thus produces most severe antenna directivity pattern distortion. On the other hand, intensity of antenna diagram disturbance is very much dependent on a particular antenna design.

For all simulated antenna arrays the most severe pattern distortion is for "diagonal" cable arrangement with alpha = 45 deg. i.e. when cable comes from front side. This is very popular and frequently used arrangement in practice. For K1FO array and, to a certain degree, for DK7ZB array this is the only bad arrangement and all other cable arrangements do not produce such a large distortion of their directivity patterns. For all other antennas "diagonal" cable arrangement produces distorted pattern for almost all alpha angle values in greater or lesser extent depending on antenna design.

Conclusion

In this article we presented results of an investigation on how the antenna array coaxial cable feeder which is arranged in a few different ways influence antenna array performance.

The presented results can now give answers to questions about the best way to guide coaxial cable for feeding an antenna array. If we must guide coaxial cable out of the antenna's symmetry plane, then results of these simulations clearly show that it is better to guide coaxial cable from the driven element near the boom and H-frame support structure as given on Fig. 2-right. Also, we found that the best cable position with minimal impact to antenna performance is practically the same for almost all antenna designs with a few exceptions of some high Q factor antennas.

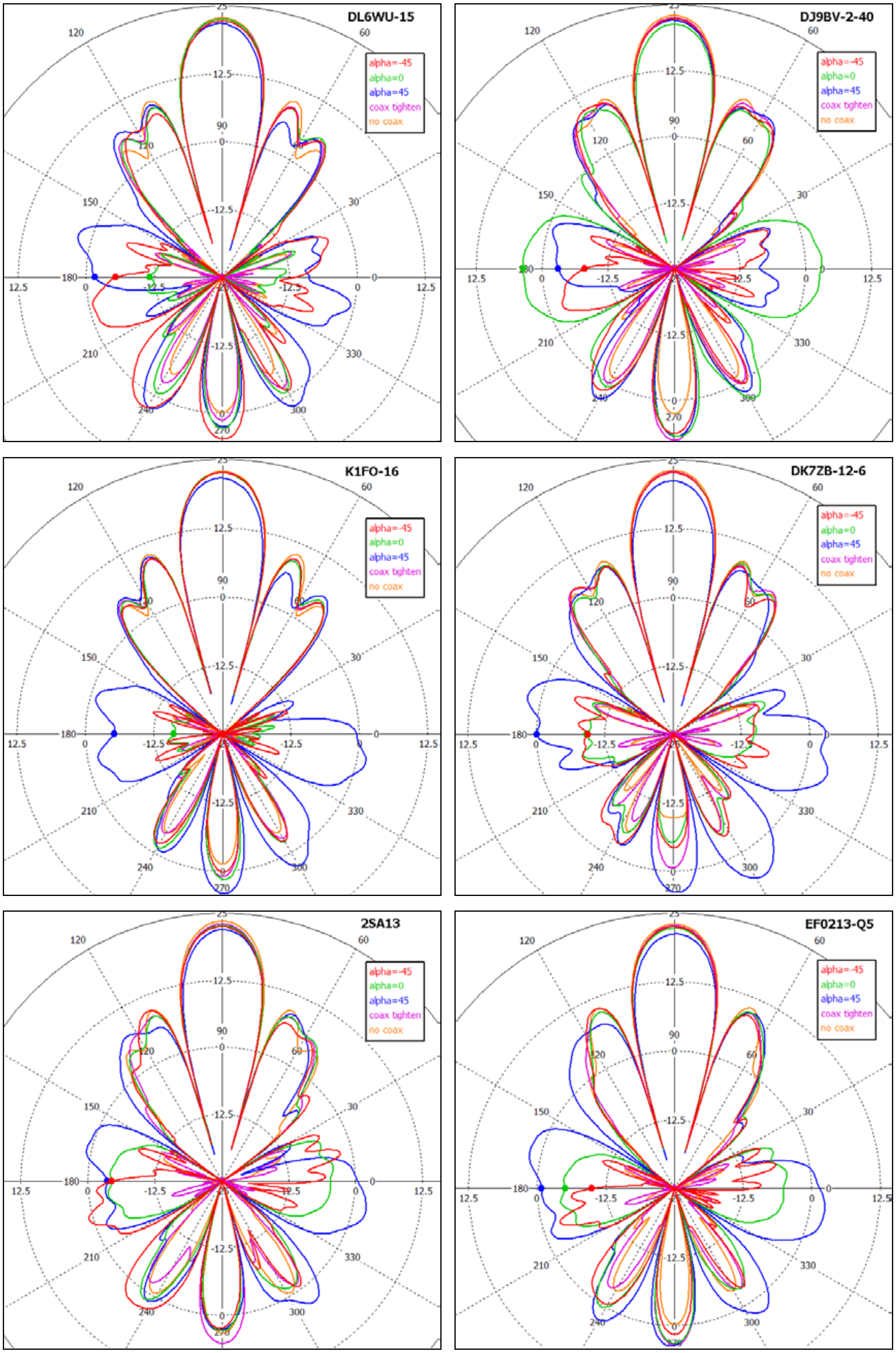


Fig.6 Radiation diagrams in E plane at 144.5 MHz for all six antenna arrays in dependence on cable arrangements

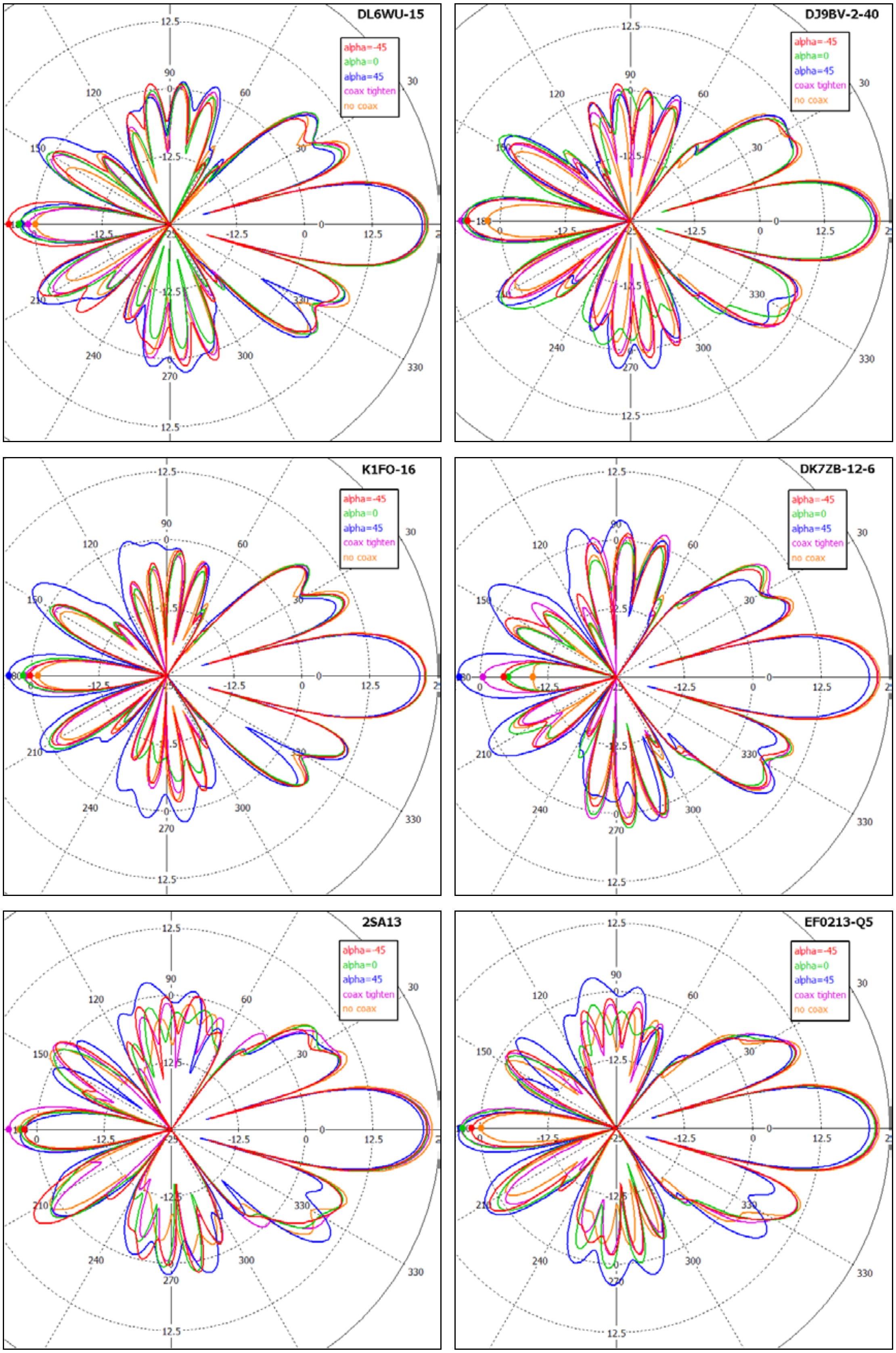


Fig.7 Radiation diagrams in H plane at 144.5 MHz for all six antenna arrays in dependence on cable arrangements

It seems that individual antennas with more suppressed side lobes and thus higher Q factor can't give any benefit in achieving better stacked antennas array directivity diagram due to its higher sensitivity to other antennas in array, cable and support structure influences. They can not take full advantage of their clear diagram because of their sensitivity to environmental influences. They usually suffer of a highly distorted diagram. On the other hand, stacked individual antennas with less suppressed side lobes and lower Q factor suffer lower environmental influence and as a result usually have less total increase of side lobes. It is clearly visible from antenna radiation diagrams that both high and low Q factor antennas have similar side lobe suppressions in stacked antenna arrays.

So, calculation of antenna effective noise temperature for stacked systems without considering cable and mechanical support structures is misleading. Even for single antenna calculation of antenna effective noise temperature without considering cable position, boom and pole structure is very inaccurate. Any ranking of antennas according to such antenna noise temperature results seems quite illusory.

These simulations unambiguously confirmed that lower Q factor antennas **[5]** and their arrays under all circumstances have less performance degradation. All of these effects to an antenna's most important performance obviously illustrate the antenna's probable behavior and sensitivity to environmental impacts in practical working conditions.

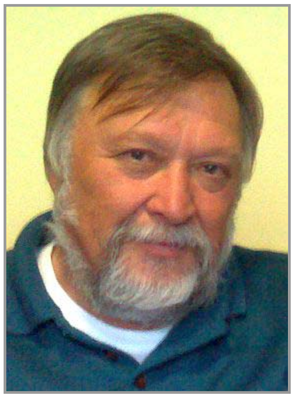
In one of the past articles **[4]** on the basis of analysis of over 50 different antennas we concluded that for the last 30 years there is no considerable improvement in Yagi antenna design. In that time this statement perhaps might sound to some too rude and underestimating. But now, with all these simulation results, we can clearly see that the best behaved antennas are those designed many, many years ago!

References:

1. Dragoslav Dobričić, YU1AW, **Coaxial Cable Feeder Influence on Yagi Antenna – Part 2**, *antenneX*, October 2009, Issue No. 150.
2. Dragoslav Dobričić, YU1AW, **Coaxial Cable Feeder Influence on Yagi Antenna**, *antenneX*, September 2009, Issue No. 149
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.

antenneX Online Issue No. 151 — November 2009
Send mail to webmaster@antennex.com with questions or comments.