THE AVANTI SIGMA 4

A vertical with some collinear gain ?

Henry HPSD 1.01 2014

The aim of this article is to provide insight into the antenna known as the “Sigma IV” or AV-174.
An antenna first produced by Avanti, (The Antenna Specialist Co.) and cloned by many under various names.

Instead of just explaining how the antenna works, the intention has been to approach the theory by looking at the information supplied on the internet and investigate the claims made.

This for the primary reason: during the background research it became clear that there is confusion about the information provided from several sources.

I hope the efforts in doing so will be successful and that it is useful for those with interest about the

“Avanti Sigma IV .”

Kind regards,
Henry Poelman
PG0DX 19PA348

CONTENT:

1 - OVERALL DESCRIPTION OF THE ANTENNA

The antenna:

A google search with just the name of the antenna “vector 4000” will provide about 50 millions hits. If we add the words “forum or debate” to google it still provides about 500,000 hits, an indication it is well known. Overall, the antenna is most commonly seen on the CB band and can be found under various names like: Sigma IV, Vector 4000, CTE saliut lw 150, Targa BT 104, Q-82, etc.
Though there are examples since 1996 available for other bands up to VHF region like FM broadcasting.

Almost every present day CB user has heard of the antenna.
In fact many have used or are still using the antenna today.

So… what does it look like:

1-LOOKING AT THE ANTENNA WE COULD DESCRIBE IT AS:

In the centre we have a 3/4 wave long conductor (some manufacturers speak of a 7/8 wave radiator) with a physical lengths for 27 MHz between 8,5 and 9,15 meters.
Around that (for CB terms) relatively long radiator we have a “cone” with 3 or 4 radials, which are about a 1/4 λ long and electrically connected to the bottom of the 3/4 wave vertical section at an acute angle.
At the top end of the “radials” there is a horizontal “loop” attached.
At the bottom you will often find a matching system in the form of a gamma-match.
And the antenna performs as a vertical omnidirectional antenna. …that’s basically it.

HISTORY
The origin of the antenna lies in the hands of a company called ”Avanti Research& Development. Inc”
Who were later bought by “The Antennas Specialist co”, In 1980 Avanti gained a Patent number: 4282531.

That patent speaks of:
A communications antenna is disclosed having improved mechanical strength, gain and reduced lateral dimensions. The antenna includes a three quarter wave length vertically disposed elongated radiating element and a plurality of one-quarter wave length diverging elements connected at their bottom end to the bottom of the vertical radiator. The diverging elements flare upwardly and outwardly from the radiator at an acute angle, typically between about five degrees and about thirty degrees. The band width of the antenna may be broadened by interconnecting the free ends of the diverging elements such as by a conductive hoop

Now we have a rough indication which antenna we are talking about we will start digging.

1-**WHAT ARE THE CLAIMS FOUND ?**

Intense work has been done by several enthusiasts who are active on *The worldwidedx forum*.
A forum which for the average CB enthusiast could be considered one of the best in the world, due to the knowledge and the way of debating from the active members. There are several topics where the antenna is discussed including links to different sources, A summary of the claims found are:

1- The Avanti patent speaks of 2.2 dB gain over a dipole.

(begin quote)
In one disclosed embodiment for use in the C.B. band, the maximum radial dimension between the antenna radiator and the diverging elements is about fifteen inches. This embodiment of the antenna exhibits a gain, when compared to a half wave dipole, of about 2.2 dB. At somewhat greater angles, where the radial dimensions are of course larger, e.g., an angle of approximately thirty degrees where the radial dimension is about four and one-half feet, the gain over a half-wave dipole antenna is about 2.7 dB.
(end of quote)

The gain figure claimed by several other manufacturers varies. To give a short indication:
6.14 dB.
5.15 dBI.
4.15 dBI (2dBd)
6.5 dB
And one speaks of a "CSF model gain figure Typically 3db over a dipole."

It is clear they are not consistent with each other and there are "terms" free for interpretation.
As it is free to imagine what a CSF gain figure is.
Neither do the terms "dB" without an indication to its reference (like dBi or dBd) provide an indication about what the gain figure actually is.

2- There are those who claim not all software can model the antenna.
They specifically mention software like: EZNEC / 4 NEC2 etc. would lack at this.
This based on two points (see: 3 and 4).

3- Online, there is a CST plot (film) available of the antenna where people claim they see a "collinear effect" and they mention: NEC for some reason is not able to provide the same insight.

4- One of the antenna world's best known antenna Elmer's "L.B. CEBIK" has said in the past two things about the antenna.

There is a "non apparent collinear effect" and "the antenna is difficult to model with Eznec".

5- One of the frequently heard claims is ….The gain will become more obvious at the distant horizon.

6- Another one is:
This antenna is beyond common knowledge as it has two currents being active on the same conductor.

7- And finally: The ARRL article about the open sleeve antenna gives an indication there is a large amount of gain possible from a monopole antenna 3/4 wave length in height.

During our analysis we will investigate those claims.
We will start with modelling as that is the starting point from which every present day antenna is developed.

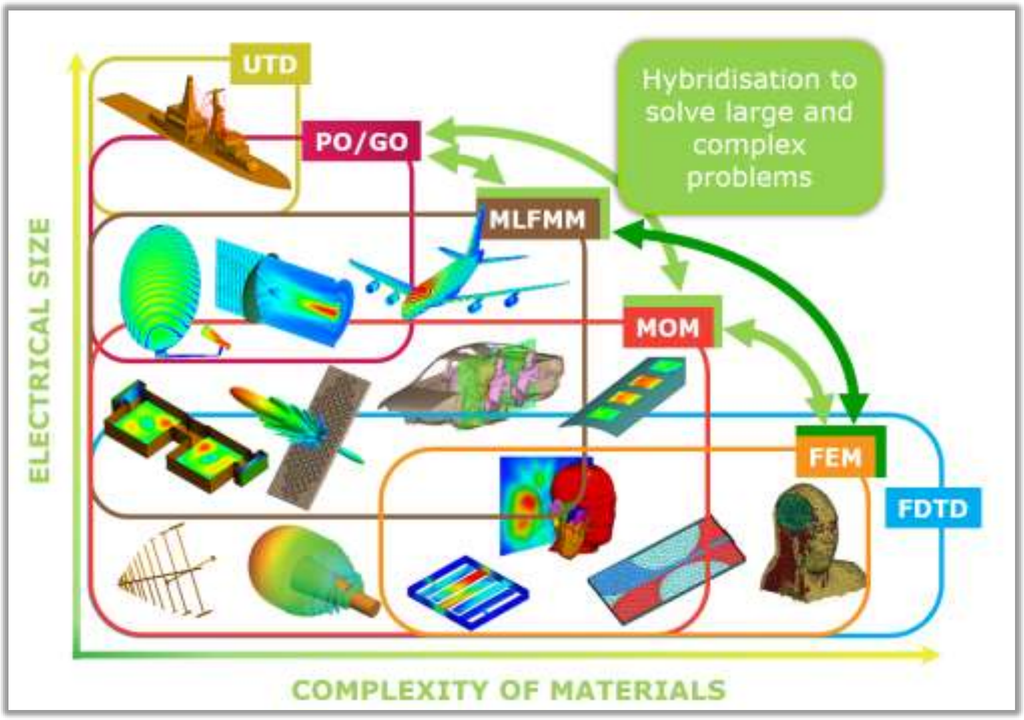
2-**CAN THE SIGMA IV BE MODELLED ?**

The question arises, can the antenna can be modelled using the Method of Moments as is integrated in antenna software like 4NEC2 (1) and Eznec (2).
Or that we need to find another solution to provide accurate information.
Although there are several who have provided a NEC based model (see appendix 2)
The validity of the models provided has been under question.
This because of two reasons: In the past there has been contact with L.B. Cebik (3) about the ability to model the antenna. He responded: "That it will be difficult to model the antenna with Eznec, and that accuracy is a point of concern". Those words are given extra strength by the interpretation by some that software like CST (4) is capable as they are under the impression that the CST analysis provided by Sirio (5) provides different results when compared with NEC.

Which Method needs to be used?

To answer the question, we need to know the limitations of NEC (MoM) and find out if other approaches like, FEM, MLFMM, FDTD would be of beneficial use. (6)

A first indication came from a seminar in which I had a conversation with Frank from CST.
I asked him: What would be the best method to model an antenna like the Sigma 4?
There was no hesitation: the answer was by using the "MOM" method.
Advanced software like CST and FEKO (7) and IE3D(8) are capable of using different methods of calculating,
The "MOM" solution and advanced MOM solvers are integrated as well.
To understand which different "solvers" could be used, another EM field software (FEKO) provides the below given indication on their website:



(FEKO ©, published with permission)

From the above picture provided by FEKO, (image courtesy of Altair, www.altair.com)
We are able to extract that:
MoM and FDTD are the initial methods for solving most antenna electromagnetic field equations.
Each "solver" has of course its limitations for us to find out how these apply to the Sigma IV.

2-CEBIK SAID "DIFFICULT TO MODEL"

As with all calculations the input needs to be correct to have a reliable outcome.
And so is the case with modelling software. Although there are many who model an antenna and publish results as "facts"" the results often lack accuracy.
Not in first place due to the limitations of the software, but more often the knowledge of the user is the key factor.
This is a problem not only limited to the average user, it is seen with commercial manufacturers as well.
It is true: Within the limitations provided that computers don't make mistakes…people do.

That brings us back to L.B. Cebik and his words.
Why would he have said that it would be difficult to model the antenna?

Sadly L.B. Cebik passed away in April 2008, leaving behind his work for which we are grateful to still be able to use. For us antenna enthusiasts it is a wealth of information. His work can be found on http://www.antennex.com(9)

After investigating his work, we notice:
He used the terms "difficult to model " in other antenna examples as well.
For instance: In his work on the coaxial monopole,
And there are other examples where he warns about possible accuracy issues with NEC that may be of influence.

What is consistent in his work is :
When he used the terms "difficult to model", it was always in combination with a solution on how it should be done to prevent possible errors.
In situations where NEC was a limitation, he has used words similar to "it can't be analysed with NEC".

2-LIMITATIONS OF MoM / NEC ?

If we summarise the possible difficulties we could encounter modelling the antenna with MoM,
it becomes clear :
There are some details that need to have attention if we want accurate information.
It is easy to make mistakes and the term "difficult to model" could be applied to the antenna for a beginner.
Although we will never know for certain, it is very plausible he indicated with his words some possible common made errors with antenna modelling using "NEC/MoM".

Some of them are:

1- *Closely spaced wires.*
2- *Wires attached to each other at an acute angle*
3- *Source placement at a segment junction*
4- *The tapering of aluminium*
5- *The ring attachment to the upwards folded radials.*

But there are others.

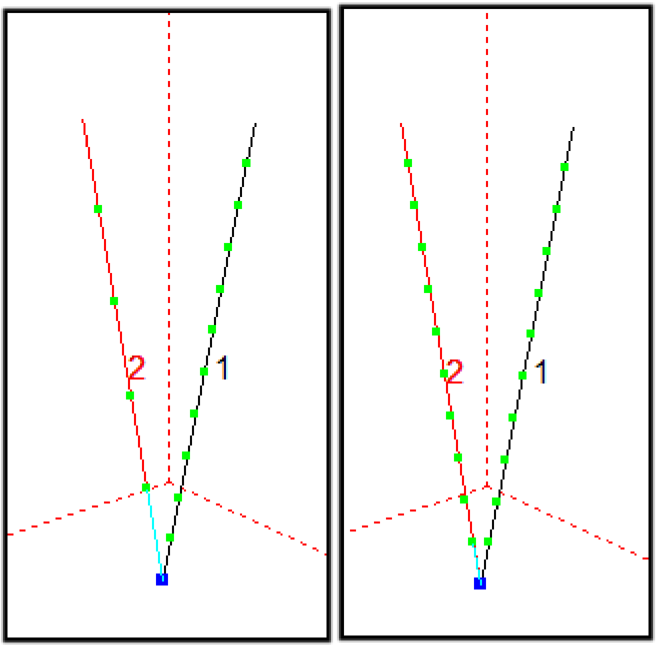
To give a brief indication we will look at the five mentioned.

2-1 Closely spaced wires.

The Eznec manual (10) provides an insight:

(quote)
When modelling parallel or nearly parallel wires which are closely spaced, it can be very important to align the segment junctions. That is, they should be directly across from each other. This is particularly true if the segment length is greater than the line spacing.
(end quote Eznec manual)

With the Sigma 4 at the bottom of the cone we have a region where parallel wires exist.
It is important to be aware of the individual segment lengths and apply the precaution provided in the manual.

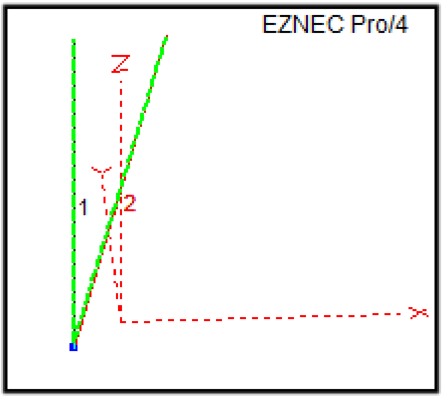


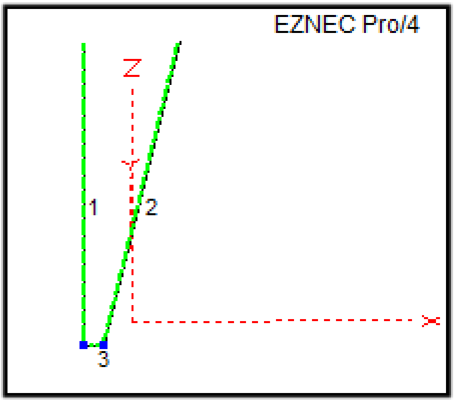
Above are Two examples of parallel wires and segment lengths.
Because the Sigma IV has wires at an acute angle it is important to maintain equal segmentation length in the main radiator as well as the radials.
The green dots represent segment connections. In the left picture wire leg 2 has 5 segments and wire 1 has 11. The manual says those segments need to be equal in order to provide accurate results as done in the picture on the right.

2-2 Wires attached to each other at an acute angle

(quote Eznec manual)
NEC has some difficulty in accurately modelling multiple wires joining at a very acute angle, such as with a "fan" antenna, the difficulty being greater with NEC-2 than with NEC-4.
(And :)
When modelling very acutely-intersecting wires, evaluate the results carefully, particularly if a source or load is at or near the junction.
(end quote Eznec manual)

As we can read, using NEC4 will already solve most of this possible challenge.
Other options would be to add a small horizontal wire between the bottom radiator and the vertical radial.

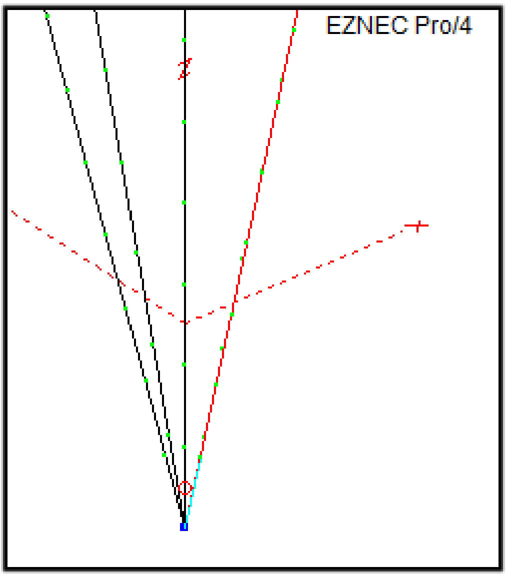


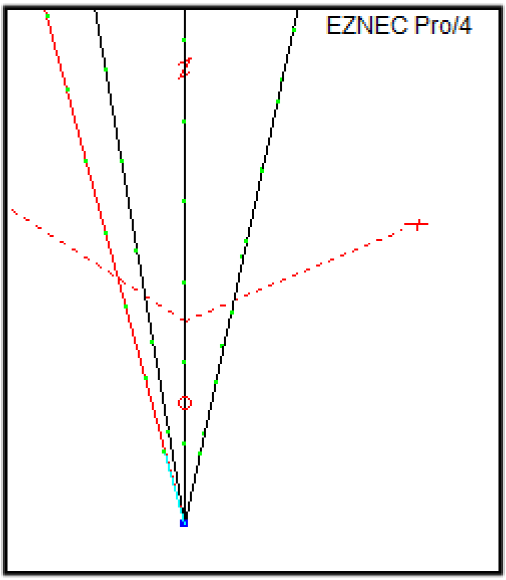


Above is an acute angle between two wires and a possible way to provide more accuracy.

2-3 Source placement at segment junctions

(quote Eznec manual)
Conventional EZNEC sources have to be placed on a segment, so simulating a source at a wire junction requires special techniques
(end quote Eznec manual)





Above we have two examples: The first with the source rather close to a segment junction and the second with the source moved slightly upwards away from that junction resolving to more accuracy.
2-4 The tapering of aluminium

(quote Eznec manual)
NEC-2 is known to be inaccurate in modelling connected wires having different diameters. (Note: This is sometimes called being "tapered". It shouldn't be confused with EZNEC's segment length tapering.)
(end quote Eznec manual)

A possible solution to this problem is: Not to use different diameters but model the antenna with a single diameter. Although we are not able to copy the exact antenna provided by a manufacturer, we are able to analyse the performance of it. There are ways to calculate the total electrical length from a radiator using “tapered” aluminium tubing. That total length can then be applied to a single diameter and you would have the same outcome.
Another option would be to use another engine. NEC 4, though more expensive is capable of handling this with better accuracy.

It is beyond this article to provide information on how one should handle all the different situations.
But in this case they are not a limiting factor of the accuracy of NEC as long as we realise what we are doing and how things should be done.

2-CONFIRMATION ?

I myself do not have a deep technical background like many of us and will never consider myself an expert.
But there are those who if they want or not, in my eyes can be considered as such.

Due to circumstances, I had the pleasure to have been in contact with: G.J. Burke of the Lawrence Livermore National Labs in California (11).
For those who do not know of him: He is one of the code writers for NEC. Someone I can imagine software writers would go to, to discuss a certain subject about NEC capabilities.

When asked: If he saw any difficulties modelling the Sigma IV with NEC ?
His reply was that the antenna doesn’t look like something NEC couldn’t handle.
Other known people (experts) within the modelling software community like:
Roy W. LeWallen (writer Eznec) (12), ArieVoors (writer 4NEC2)(13) as well as Brian Cake(14) and several people from CST all provided the indication that MOM is capable.
This is of course: if done correctly.

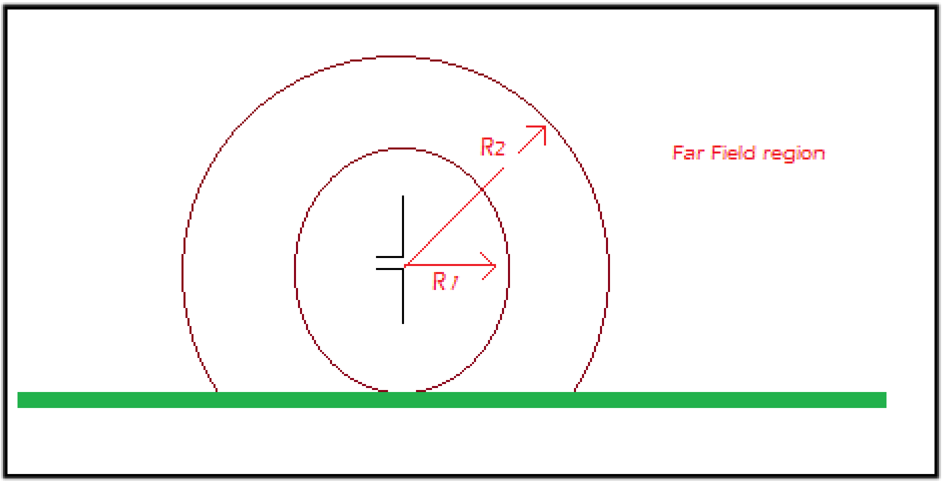
Thankfully, there are several ways to verify if the model is correct without asking a knowledgeable one.
One of them is the Average gain factor. Software like 4NEC2 and Eznec and others have such a verification tool.
The average gain factor is the total far field power divided by the power applied to the source.
That factor should be in the order of 1, if it isn’t there is a good indication that there is something wrong with the source placement.
There are more options which go beyond the nature of this article.

3- An antenna has several regions:
(the theory explored behind the claims)

3-Regions

We can divide the radiation from an antenna into several regions.
These fields are specific areas (space) around an antenna.
Different regions (areas) have different names and represent different distances from the antenna.

Close to the antenna we have: *The reactive near-field region*,
Beyond that region we call it: *The radiating near-field region*, also known as the "Fresnel region".
And eventually we have *The Far-field region* (Fraunhofer)



It is difficult to express the exact point of transfer from one region to another, as they gradually "change" from one to the other. For a approximate indication, antenna engineers use the description given by C.A. Balanis.(15)

C.A. Balanis speaks of:

Reactive near-field region: $R < 0.62\sqrt{D^3/\lambda}$ *.... (+/- 5 meters from the antenna)*
Radiating near-field region: $R < 2D^2/\lambda$ *.... (+/- 15 meters away from the antenna)*
Far-field Region: $R > 2D^2/\lambda$ *.... (+/- beyond 15 meters away from the antenna)*

Where R = distance, D = the antenna maximum antenna size and λ the wavelength all provided in meters.

Those `regions` can be divided again into other `regions`. For now, we will focus on the `near field fields`.

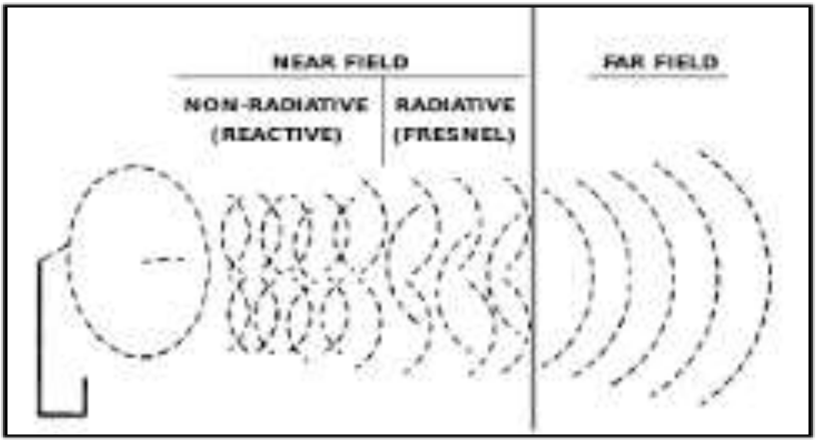
3-The `NEAR FIELD` can be divided into the:

The Electric field (E), and the magnetic field (H).

For the purpose of analysis an indication of those fields is very interesting, however we can't draw a conclusion on how the far field will be formed from the near-field region as the far field is not "established" yet.
The "antenna" is still working on its far field radiation pattern.
We can't provide any details about antenna gain in the far-field region from that near field plot.

Perhaps that's difficult to understand.
So imagine we are looking at a car.
It is parked somewhere and the engine is running, we take a glimpse inside and a look at the gasoline indicator. (Looking at near field)
From that we draw the conclusion: It will be driving 100 Km with speed of 50 Km/hr (far field).
It is obvious that would be a rather strange conclusion…: We would have no idea what is going to happen.
Perhaps we will just turn the engine off and wait until the owner returns.

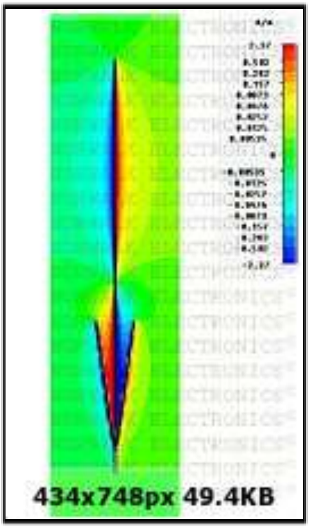
A picture from Wikipedia tries to explain the interaction:



3-THE CST PLOT.

A very interesting film has been provided by Sirio and can be found online from several hosts.
Although to my knowledge Sirio has not claimed to prove anything with the film, there are others who have based their theories on it. The collinear theory is for example partially based on that film.

The animated film we are talking about looks like this:



(single frame as the film can be found online)

Why is the "famous CST plot" of interest?

As mentioned: some conclude the CST plot provided is proof that the Sigma IV is a collinear antenna.
That finding is based on the interpretation that the above plot shows *antenna current and phase* and that we can see that the current within the cone is "confined" and remains in the cone, where current on the outside of the cone can add to the gain due to its being in phase with the top 1/2 wave section.
And in all honesty, I understand the confusion. It is certainly not something that the average CB or HAM operator will interpret correctly.

What is it?
To understand what the CST plot is actually providing, we need to find out what it is indicating.
We have a couple of indications:

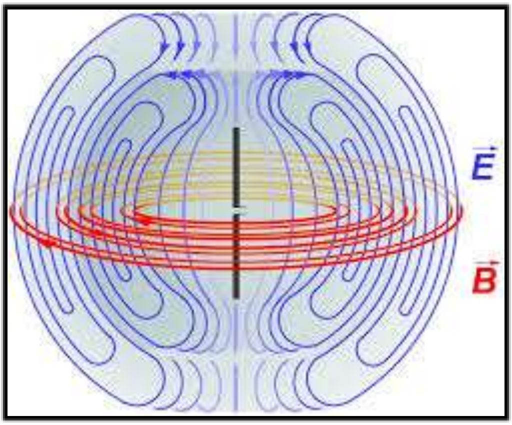
- We can draw a conclusion from the size of the antenna in combination with the shape of the pattern.
  For us to notice:
  That because we can see differences between the inside and the outside of the cone it indicates that we are looking at close range to the antenna. In antenna terms that would be the "near-field".
  The CST plot is within the calculated" 5 meters distance away from the antenna".
  It is the reactive near-field region we are looking at.
  In the reactive near-field there are two major fields active, The Electric field and the Magnetic field.
- The magnitude and the colour are expressed in A/m. (top right corner)
  The unit A/m is being used to express the density of the magnetic H field.
- The confirmation that it is: The circular magnetic H field in the near-field region comes from the magnitude and the distance provided :

As the "magnitude" of the magnetic H field will vary with distance and will lose strength with the cube of distance from the antenna ($1/r^3$) as can be indicated from the plot.

This is different from far field radiation where field strength decreases with distance from the antenna at a slower rate: ($1/r^2$).

3-THE COULOR INDICATION :

To understand what the colours are indicating, we need to know some Electromagnetic basics.
Imagine an antenna with a RF wave signal going into it (keeping in mind we are still looking at the "near-field).
We will discover there will be two fields established.
There is an electrical field (E) and for us the important magnetic H field.
Those two are at a 90 degree angle to each other and both can be imagined like this:



The above image `represents a half wave dipole and the near fields surrounding it.

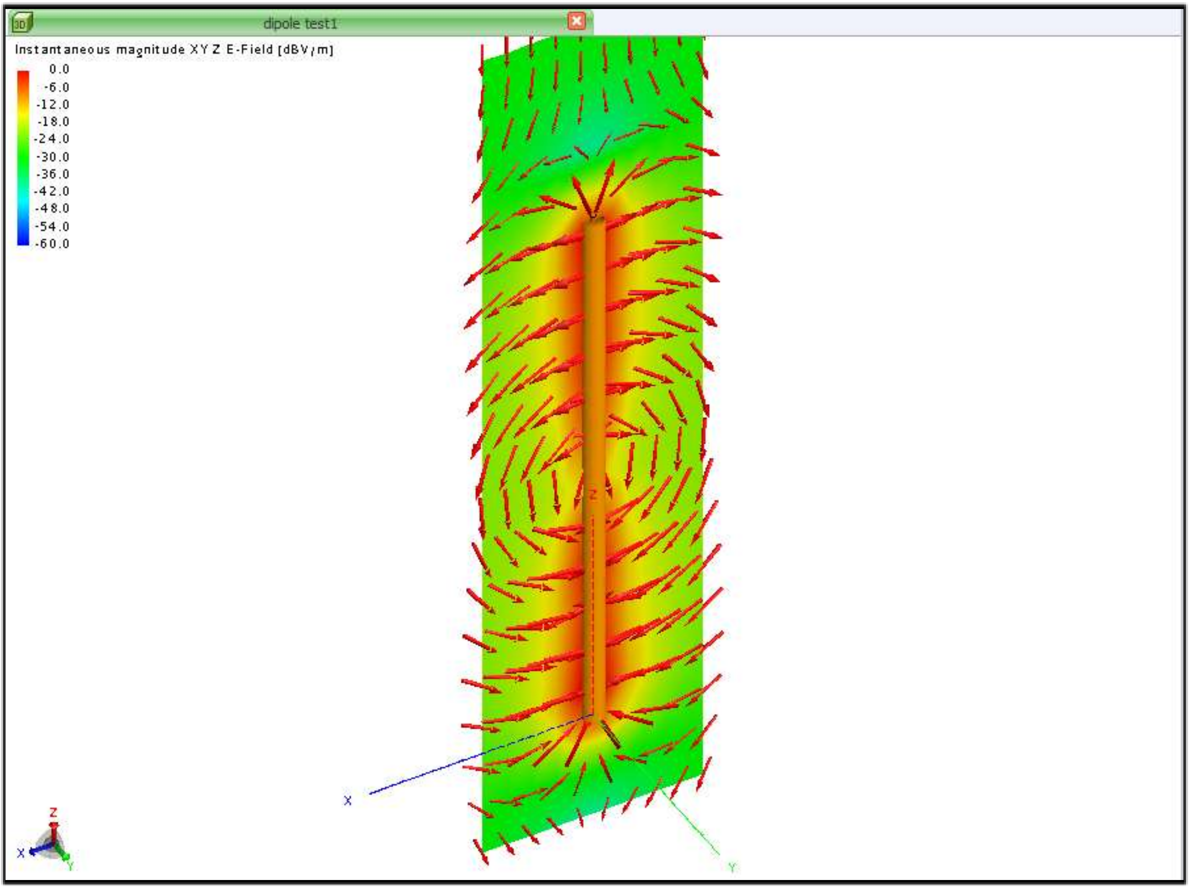
A common mistake made is: that the E field combined with the H field are the "far field".
I realise it would be "easy" to see it like that. It is just a bit more complicated.
We can't just add them together.
For those interested it is really worth investigating books like "antenna theory" from C.A. Balanis.

LOOKING AT THE "RED B":
The magnetic H field has a "magnetic flux direction". Looking at the picture it looks like the RED magnetic H field is rotating, but one should see it more or less as a direction indicator. The direction will depend on the period of the RF cycle applied to the antenna. This is different to the conclusion some have made, that they think they are watching antenna current and the phase angle of it.
Although antenna current and the magnetic H field are related (magnitude) they are different.

The magnetic H field expanding away from the antenna will lose strength, it is round and has magnetic flux direction depending on the phase angle of the RF wave.

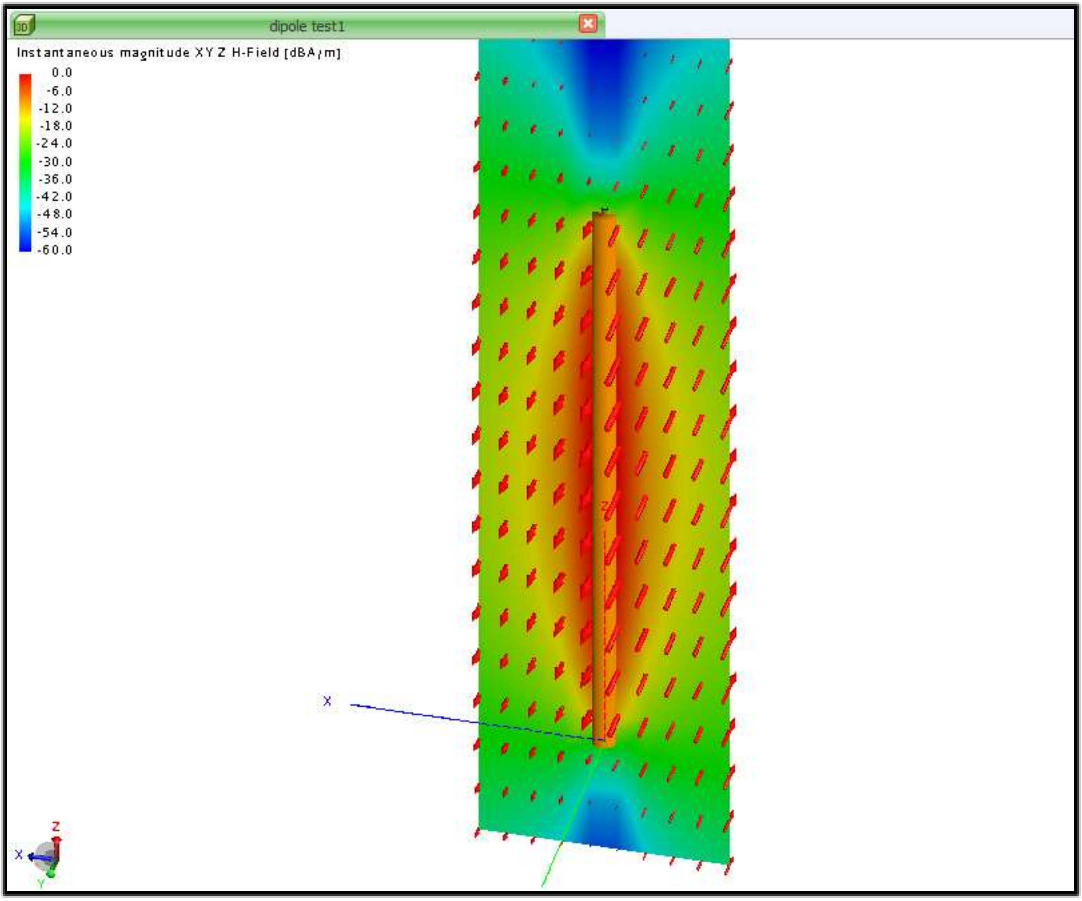
3-PLOT E-FIELD DIPOLE

To provide more insight about this, I have modelled a centre fed dipole in FEKO.
Below is a view of the E field (near-field region) including arrows to indicate directions.



3-PLOT H-FIELD DIPOLE

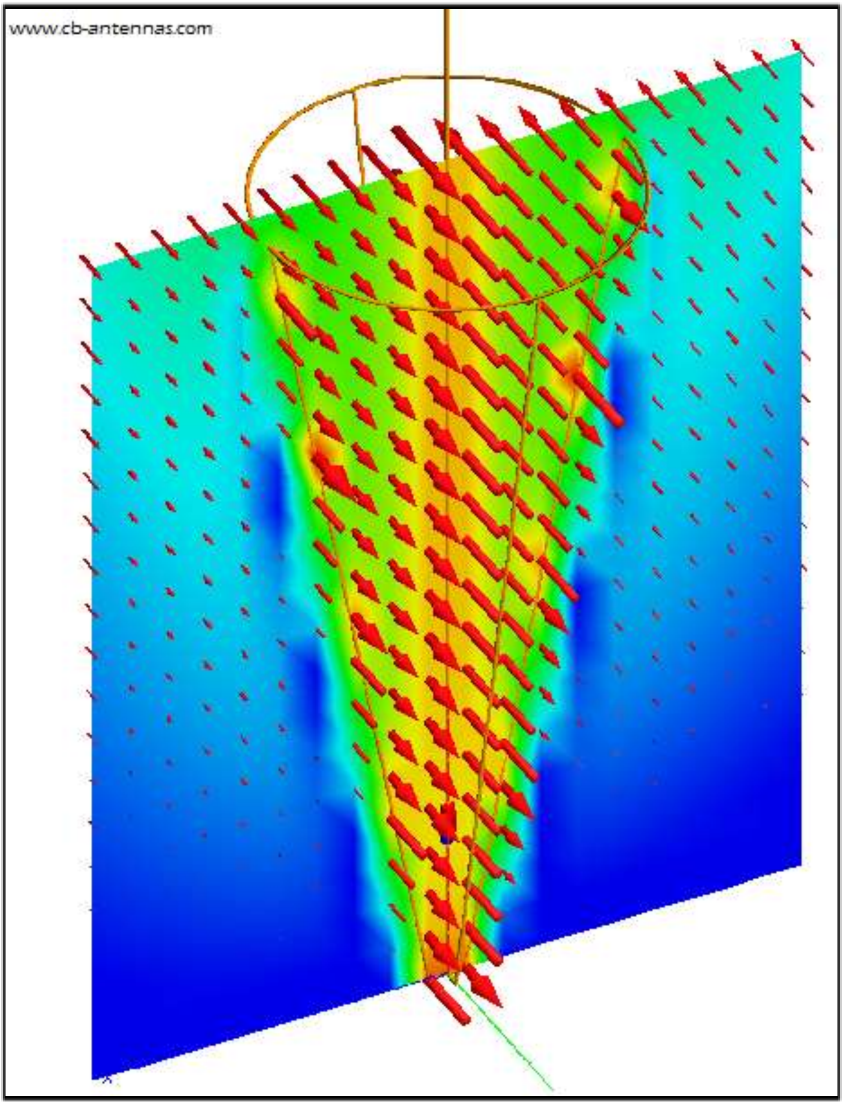
And the magnetic H field (near-field region) of a centre fed dipole in FEKO provided below including arrows to indicate direction.



Please notice that the arrows point in the opposite direction of the vertical dipole!
Try to imagine horizontal circles around the dipole and the arrows are indicating direction.

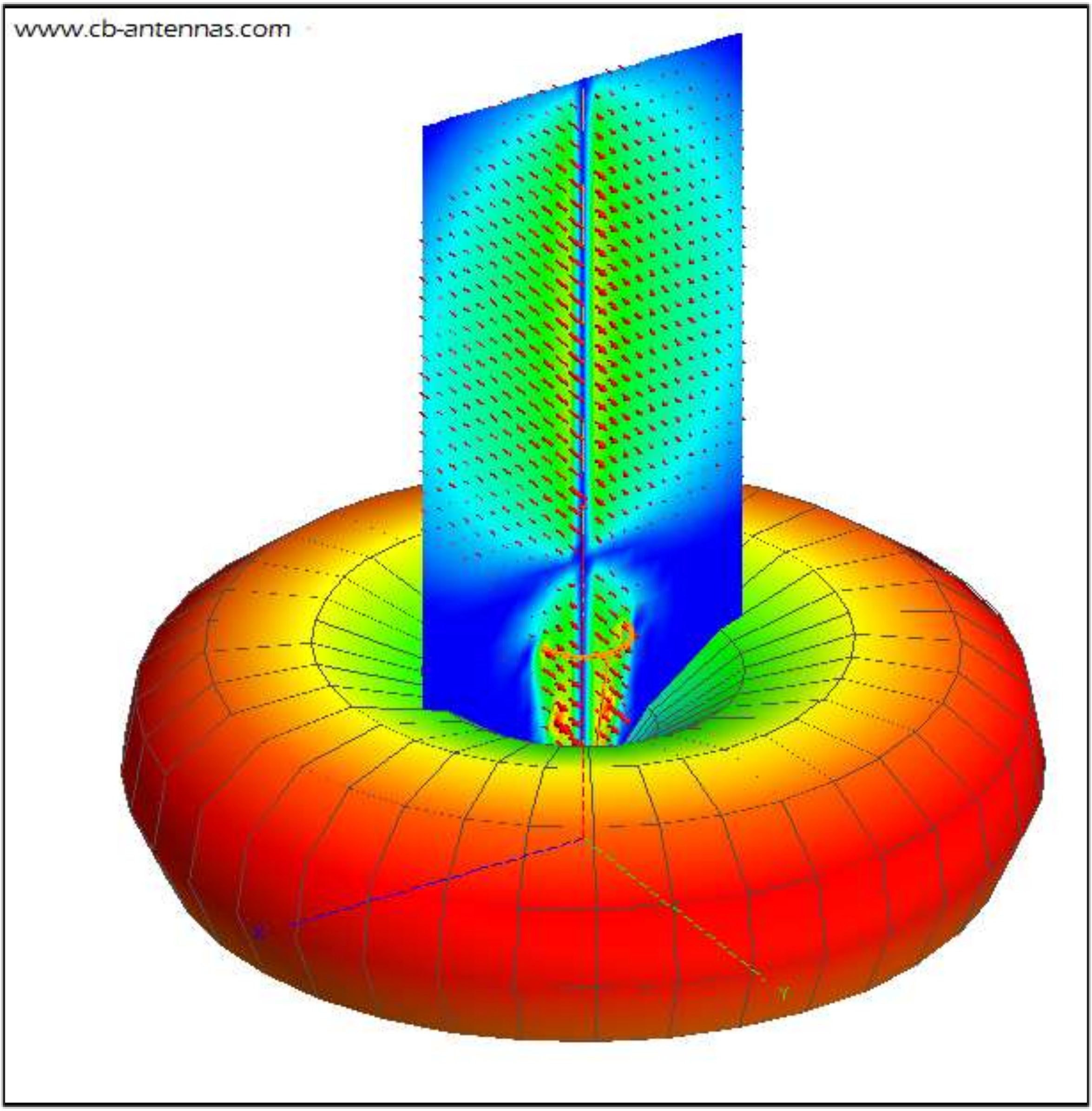
3-PLOT H-FIELD CONE SIGMA IV

If we look at the magnetic H field in the sigma IV cone by using FEKO we can provide the image below:



3-PLOT SIGMA IV H-FIELD and FAR FIELD

And finally a combination of the far-field pattern and the magnetic H field (near field) including arrows for direction.



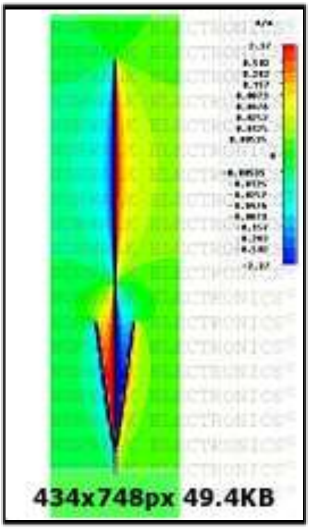
In the above I have situated the far field plot at the bottom of the antenna to provide “direction” indication in the cone.

To determine the direction of the of the magnetic (near) H field we can apply the so called “right hand rule”:

- The current direction is provided by the direction of the thumb
- The magnetic field by the direction of the fingers (90 degree from thumb / conductor)
- And the direction of that field is in the direction where the fingers are pointing.

4 Perhaps we are now able to understand what the CST film (plot) is providing:

Conclusion:



1) In the right top corner we see the magnitude expressed in A/m.
2) The value has two “maximums” they reach + 2.37 and – 2.37.
3) The magnitude (shape) looking at the plot on both sides are “equal”.
4) Watching the film you will notice the “distance” or magnitude is always equal on both sides during the different phases in the RF cycle.
5) The strength will decrease according to near H field radiation.

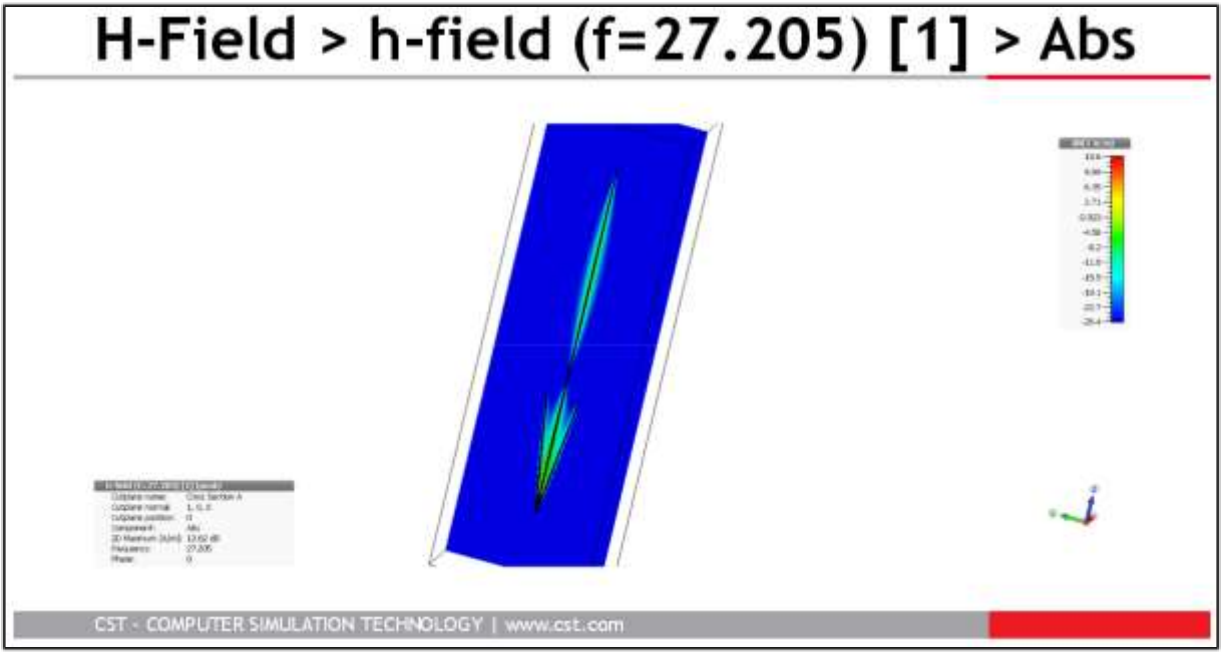
The distinct difference between the “colour” is:
On one side we have a “+” sign and on the opposite side a “-“sign.

With the information provided from the previous pages there is only one conclusion:

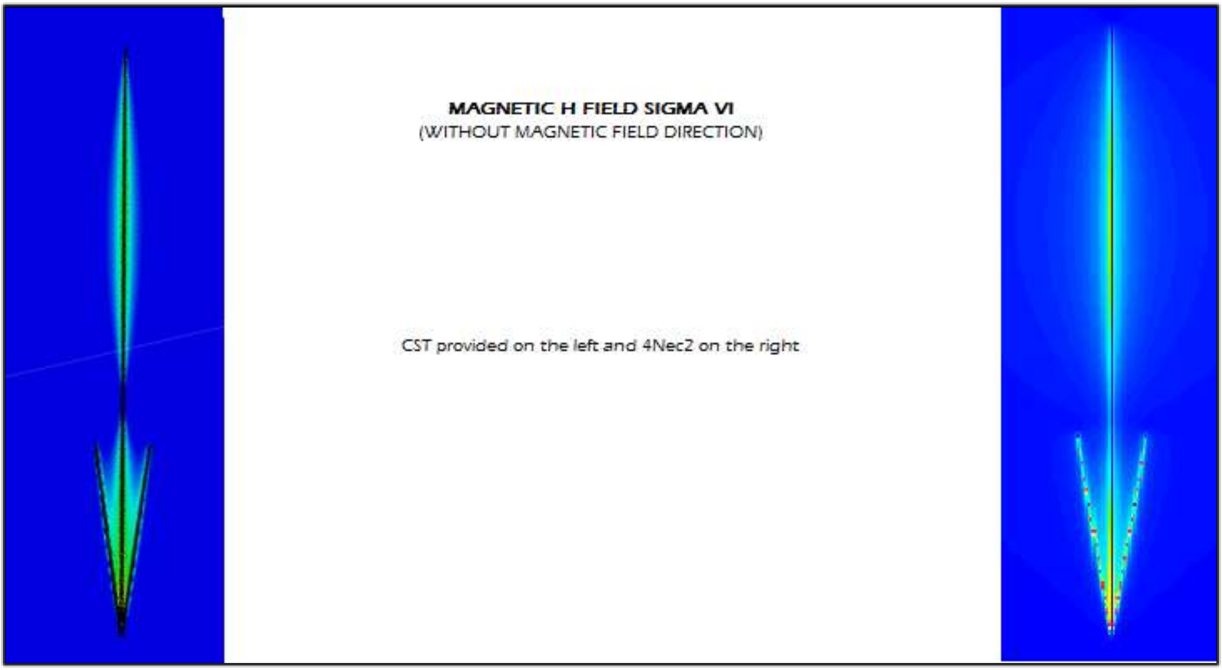
<u>The discussed CST plot is showing “The direction and magnitude of the (near) magnetic field H field”.</u>

4-HOW DOES IT LOOK WITHOUT DIRECTION?

I have been in a position to ask those with access to CST, if they could model the Sigma IV and provide the plot without magnetic flux direction indication. The plot that remains can be seen below:



And now we have a view of something that can be seen using free software like 4nec2:

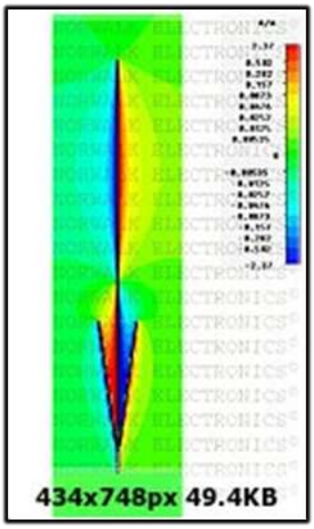


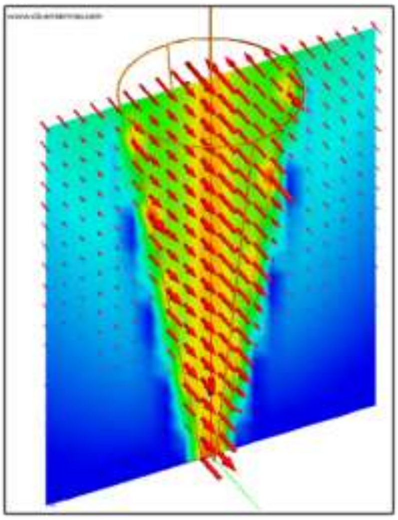
And now we can see that besides the slight difference (due to different software freq/power/max scale etc)
They are telling us the same story.

CST AND 4NEC2 ARE PROVIDING SIMILAIR RESULTS!

4-WHAT CAN WE LEARN FROM THE PLOT?

Now that we realise what it is that we are watching,
Perhaps we can gather knowledge about the antenna from the plot.
The reason why the colour density is so “bright” (red left / blue right) between the main radiator and the elements of the cone is that all the arrows in that region in the FEKO plot are pointing in one direction,
This actually provides us insight into how the antenna is working.





It can only indicate:

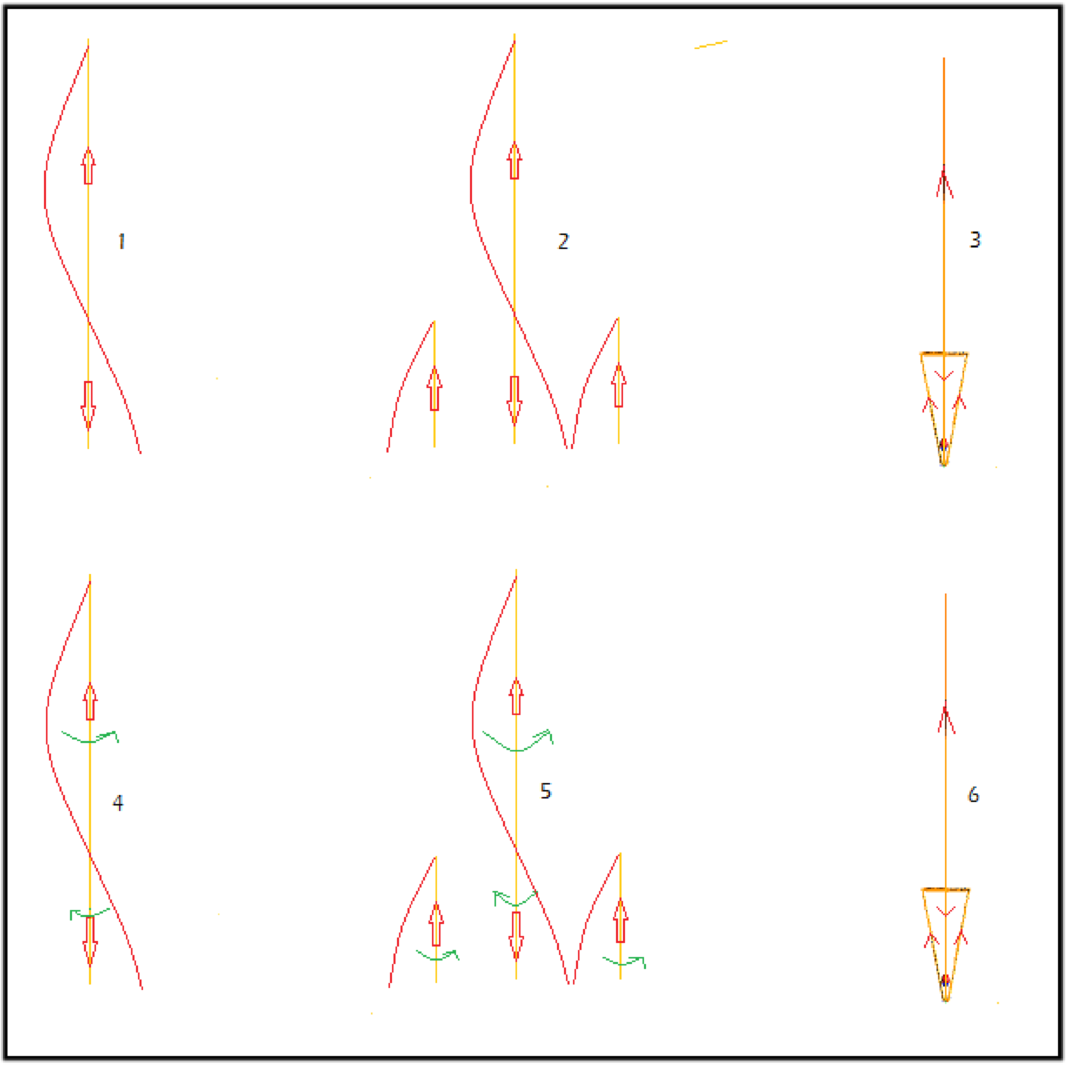
The current on the main radiator is travelling in the opposite direction to the current in the radials.

4-WE ARE GOING TO START DRAWING, FINALLY "GETTING SOMEWHERE" !

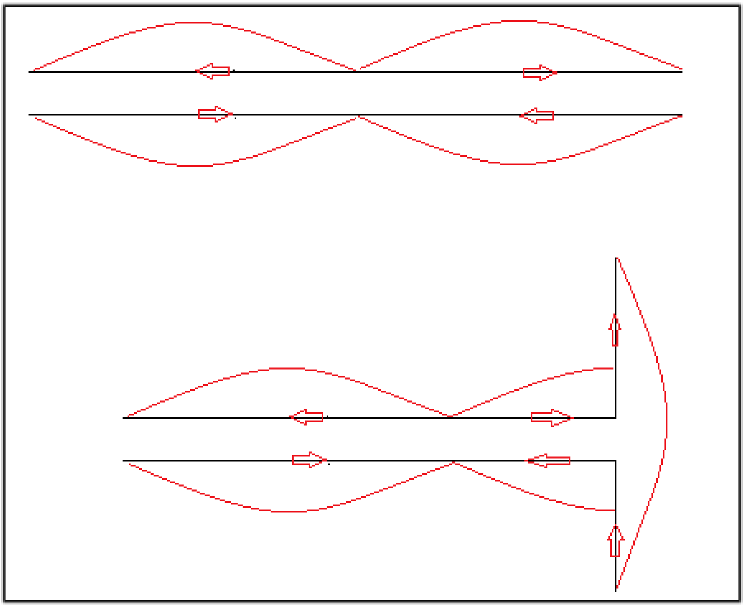
Below a simplified drawing of the currents and the magnetic H field direction;

1- Just the 3/4 wave radiator alone with the current in red and the direction of the current displayed by the arrow.
2- The 3/4 wave radiator including 2 elements in a vertical position next to it.
3- The Sigma 4 with current arrows indication.
4- The 3/4 wave radiator with current arrow indication and the direction of the magnetic H field displayed by the green arrows.
5- The 3/4 wave radiator with 2 vertical radials. Providing current direction and magnetic H field direction.
PLEASE NOTICE THE DIRECTION OF THE MAGNETIC H FIELD ESTABLISHED BETWEEN THE RADIATOR AND VERTICAL RADIALS ARE IN THE SAME DIRECTION !

6- The Sigma IV: now please draw the direction of the magnetic H field.



And that situation is actually not that strange, we notice the same thing happening with a transmission line. In fact it is often used to explain the basics of how an antenna radiates.



In the above drawing we see a transmission line (two black horizontal lines) the current and magnitude are displayed by the arrows and the red curved line.

Although a transmission line (open line) will have a magnetic and electric field around it, in an ideal situation it will not radiate. This because the currents are opposite in phase and equal in magnitude “cancelling”…hence no radiation.

We know that the transmission line has a E/M field around it simply because there is current moving.
That E/M field around an open transmission line is why coax was invented.
An open transmission line has some inconvenient aspects:
We should not install an open line near obstacles (especially metal) because the E/M field around that line will be influenced.
In a coax cable the E/M wave remains “inside” the coax (ideal).
This is due to the Faraday Shield Effect.

So what happens if we start bending the ends of the transmission line?

If we start to bend the last 1/4 wave ends of the transmission line and set them 180 degrees apart, we can see that the currents are in the same direction and no cancelation takes place, its free to “radiate”.

And above is the initial explanation of why a dipole antenna can radiate.

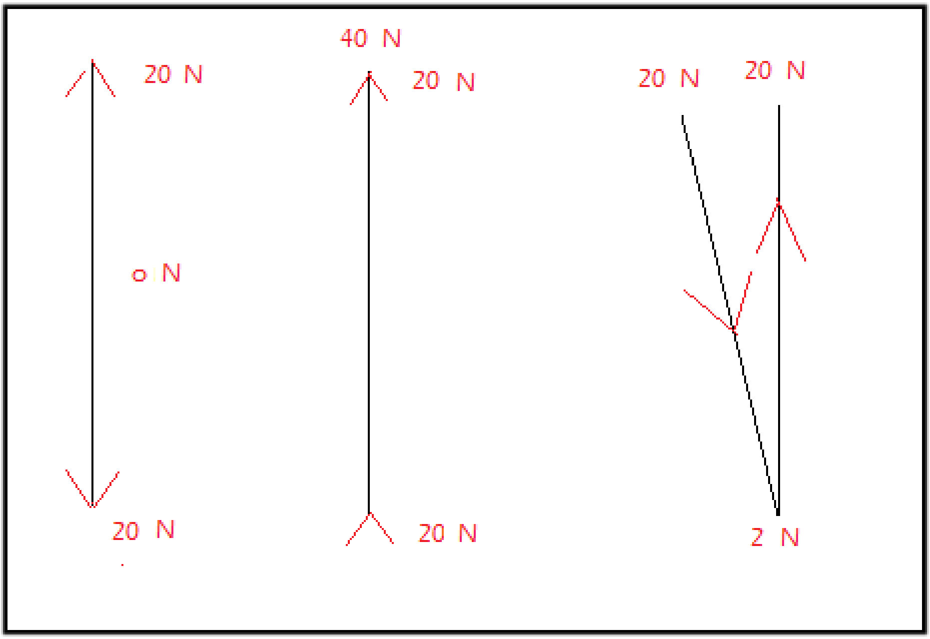
4-THE CONE NOT A TRANSMISSION LINE?

The transmission line effect is the same thing that is happening with the Sigma 4 antenna.

There is one difference:

The lines are not parallel; they are situated in a "cone" configuration. That is a reason that it is not a perfect balanced cancelling system, Secondly the top of the cone "sees" air, where the bottom 1/4 wave radiator "sees" the end of a 1/2 wave radiator. Those two have different impedances also providing some "unbalance" in the "transmission line effect"

To imagine this try to think you're with two people and they are both pulling on a rope at the same time



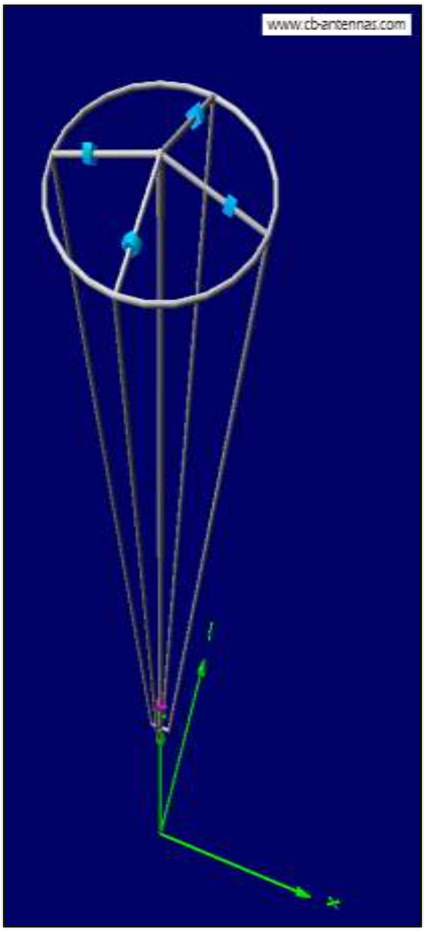
First we have two people pulling in opposite direction with equal force, the net result is 0, and they are not moving. Secondly we have two people pulling in the same direction. The combined result is "plus" and they are moving. In the third we have the "forces" in opposite direction, but at an angle. The combined result will be that they are moving….but very slowly.

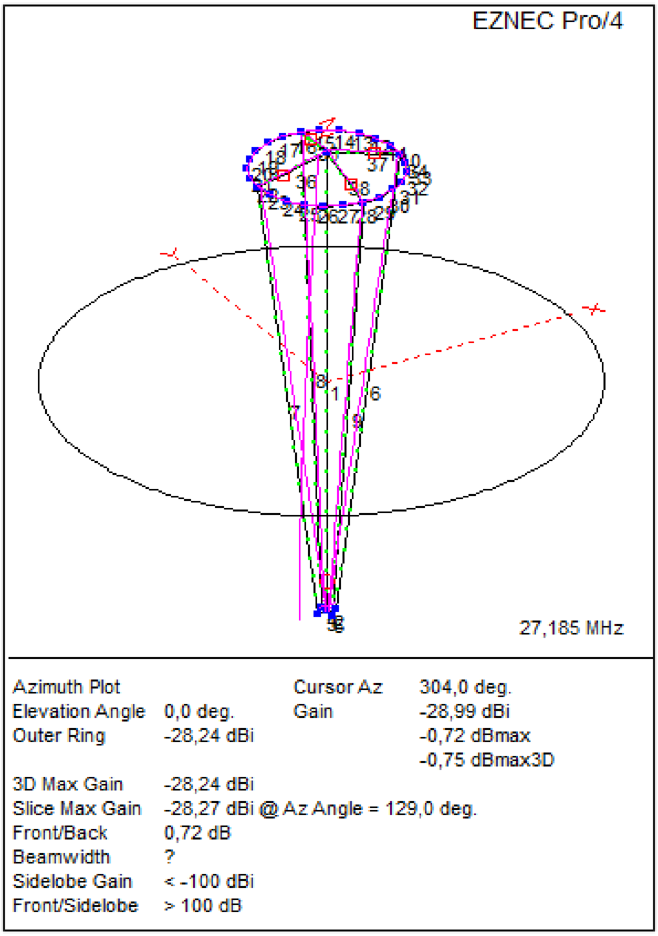
The above is analogous to the "sum" of active currents

As it is not only the transmission line mode currents that are active.
If a conductor "radiates" and there is metal near that conductor a current will be induced in that other "metal" part.
If you imagine a Yagi-Uda beam, this becomes a bit clearer. Although the parasitic elements are not directly fed, the radiation from the radiator will induce a current in the other elements…and if element length & distance are optimised we have gain or front to back etc.
MoM software is able to provide the sum of the combined active currents .

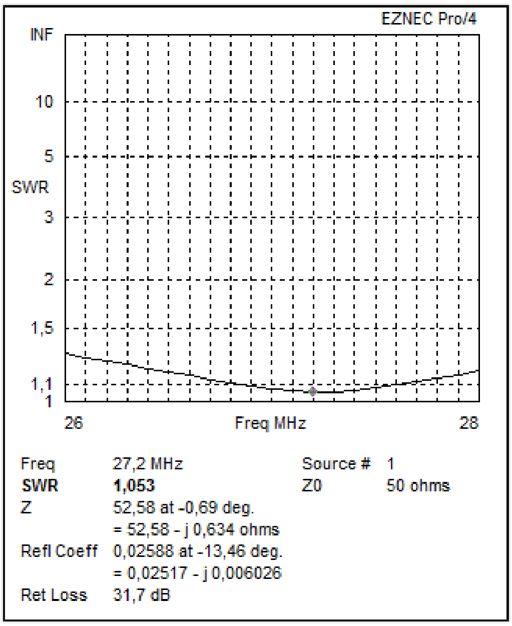
We can divide the Sigma IV in two different sections: The top 1/2 wave and secondly the cone.
We know that because the 1/2 wave on top of the cone will present a high impedance at that point.
We are able to remove the ½ wave radiator and insert a "load".
If that load represents the impedance of the end fed 1/2 wave we can find out:

How the cone behaves on its own, without the radiation of the 1/2 wave on top.
A situation we can visualize as: adding a dummy load on top of the cone.





Above is the cone with a load inserted instead of the 1/2 wave radiator.



And the provided SWR plot of the cone with the loads inserted instead of the 1/2 wave radiator.

The analysis of the cone with loads inserted provides proof there is some radiation from the cone due to the effects mentioned. The gain is in the order of -28 dB, which is still a lot better than a dummy load but not high enough to be a large influence.
The influence of that amount on the entire system will become clearer in chapter 5.

Those "effects "mentioned are currents not completely cancelled and currents that are active due to near field coupling.

And that is most likely what Cebik meant with: "non apparent collinear effect" which was one of the questions we were hoping to find an answer to (point 4 page)
As the term "collinear" gives an idea we have two currents "working" resulting in a single current "net result".
And "non-apparent is most likely to indicate it is not in a way most think about "collinear" theory.

When Cebik mentioned the "non-apparent collinear effect", he never mentioned that it would be of a significant amount or that it will be beneficial though he did mention it:
That he preferred not to go into detail as he imagined it would be difficult to understand for the average Sigma4 user.

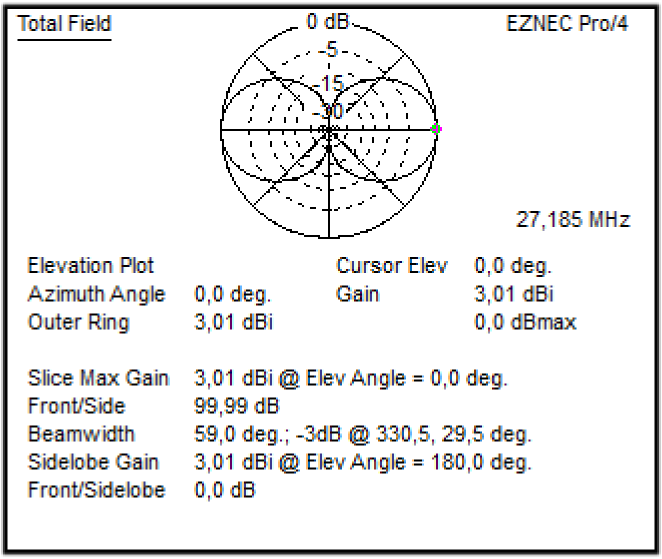
We now have an indication there is some radiation from the cone, but we still need to find out if it is contributing to the performance of the entire antenna.
Will it contribute to the radiation at the angle we want it to be or is it pointing towards the sky for instance.

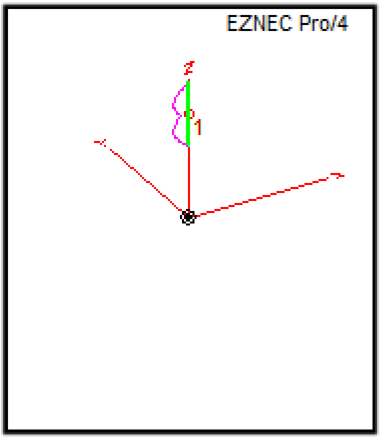
That brings us to the question: what gain can we expect from the Sigma I

5 WHAT GAIN CAN WE EXPECT FROM THE SIGMA IV ?

Gain from a monopole 3/4 radiator.

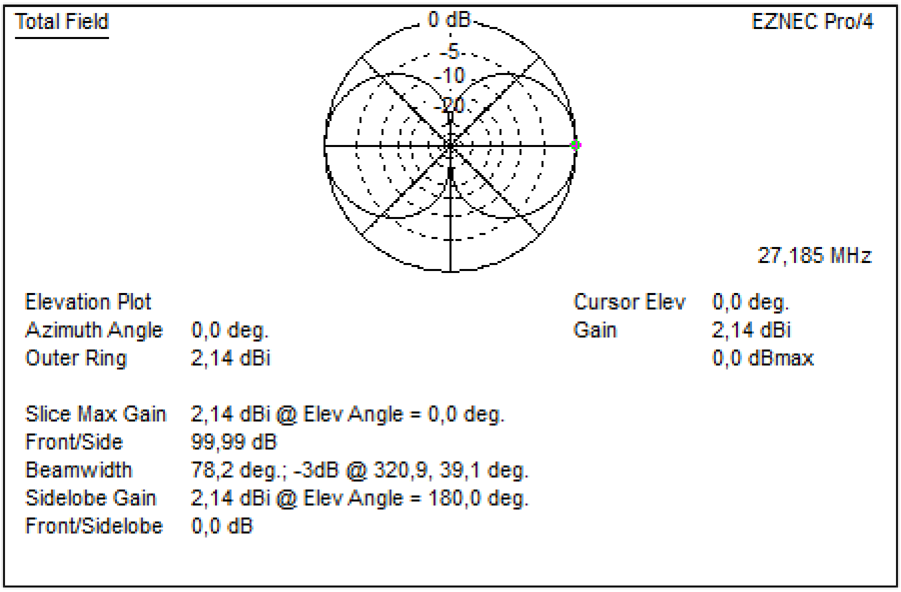
If we start approaching the question logically, we know a centre-fed ¾ wave radiator is capable of producing about 3 dBi (free space).
If we use such an antenna and feed it at the bottom (end fed) the roughly “1dB” gain over a dipole will not be noticed because the main lob is pointing to the sky.





Above a 3/4 wave centre fed dipole.
The Sigma IV is a 3/4 wave antenna where the bottom part 3/4 wave is acting as a transmission line where not all currents are cancelled but most of them are.
For that reason the gain of a sigma 4 can never be higher than 3 dBi, but will be lower.

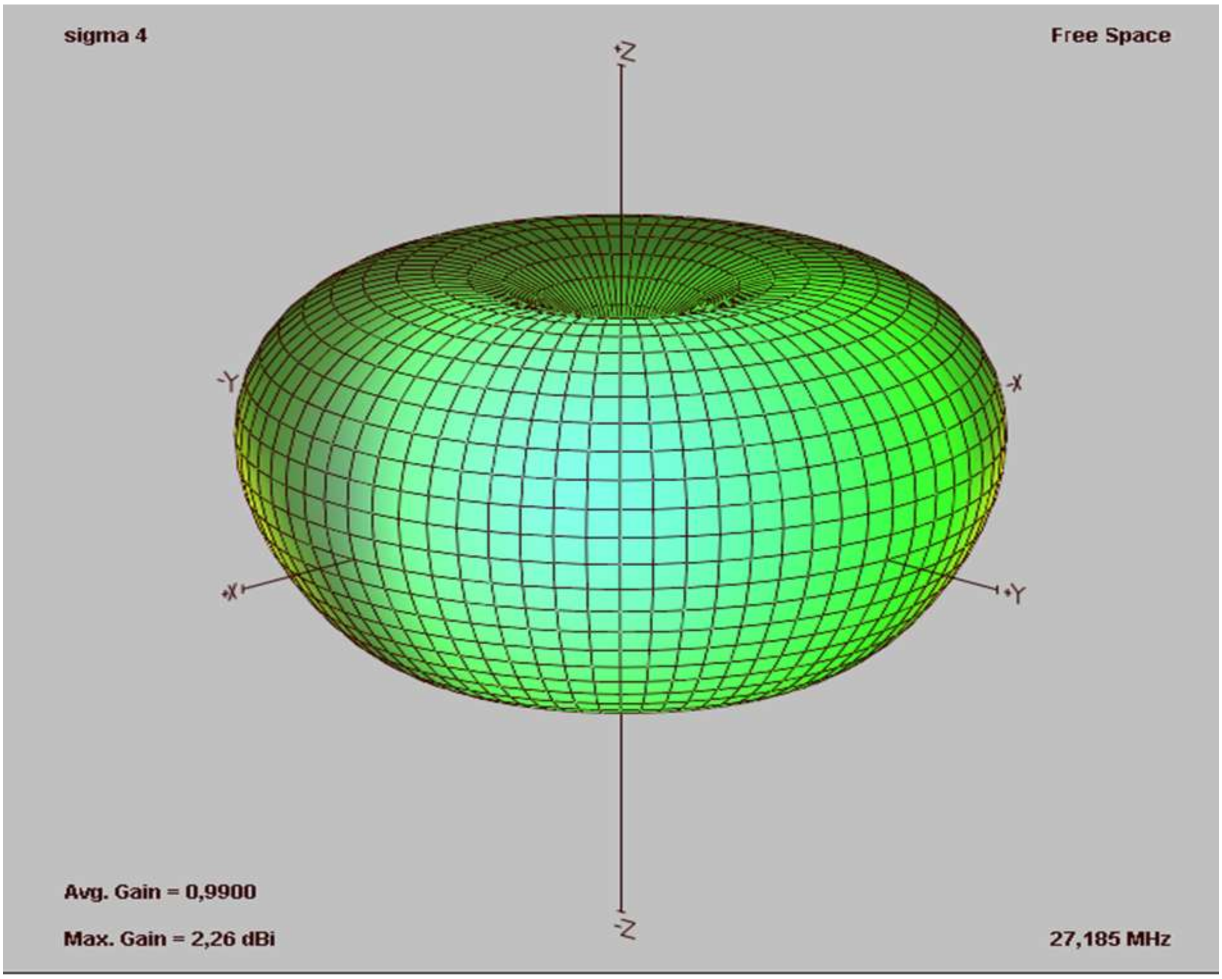
And gain will be higher compared to a dipole (2,14dBI) because we do have some radiation from the cone.

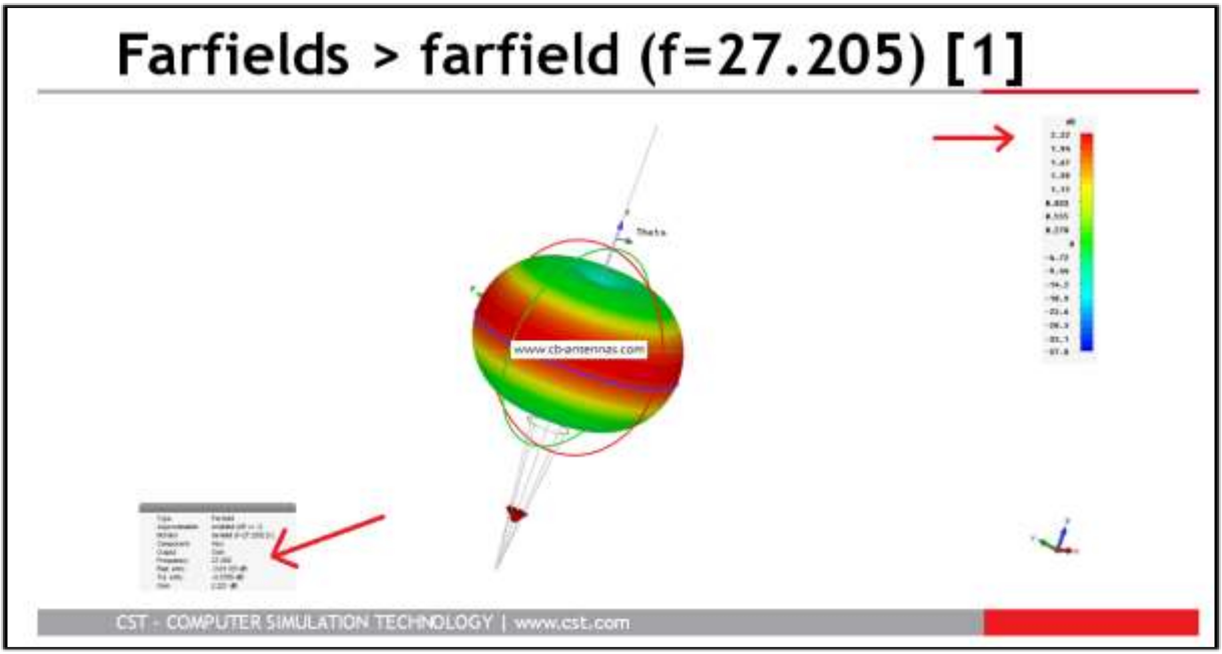


Above the elevation plot of a dipole in free space providing : 2,14 dBi

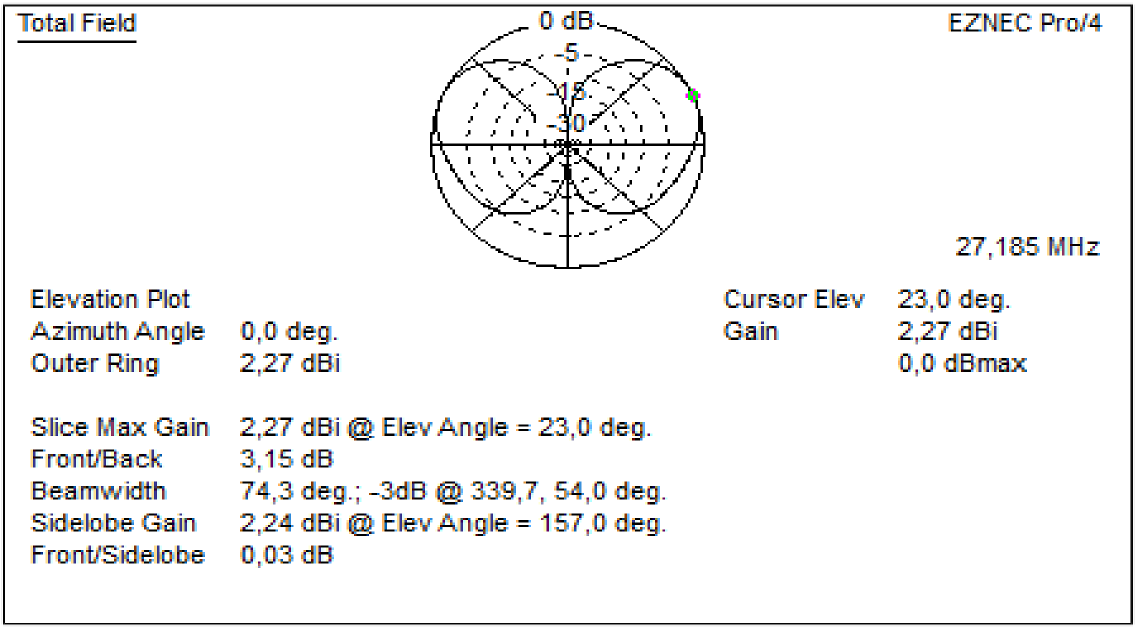
5-SIGMA IV FREESPACE GAIN:

Modelling the antenna with a Mininec3 engine, developed by J. C. Logan and J. W. Rockway at the Naval Ocean Systems Centre in San Diego gives us the result provided in the plot below. The software used was: “antenna model software from “Teri software”



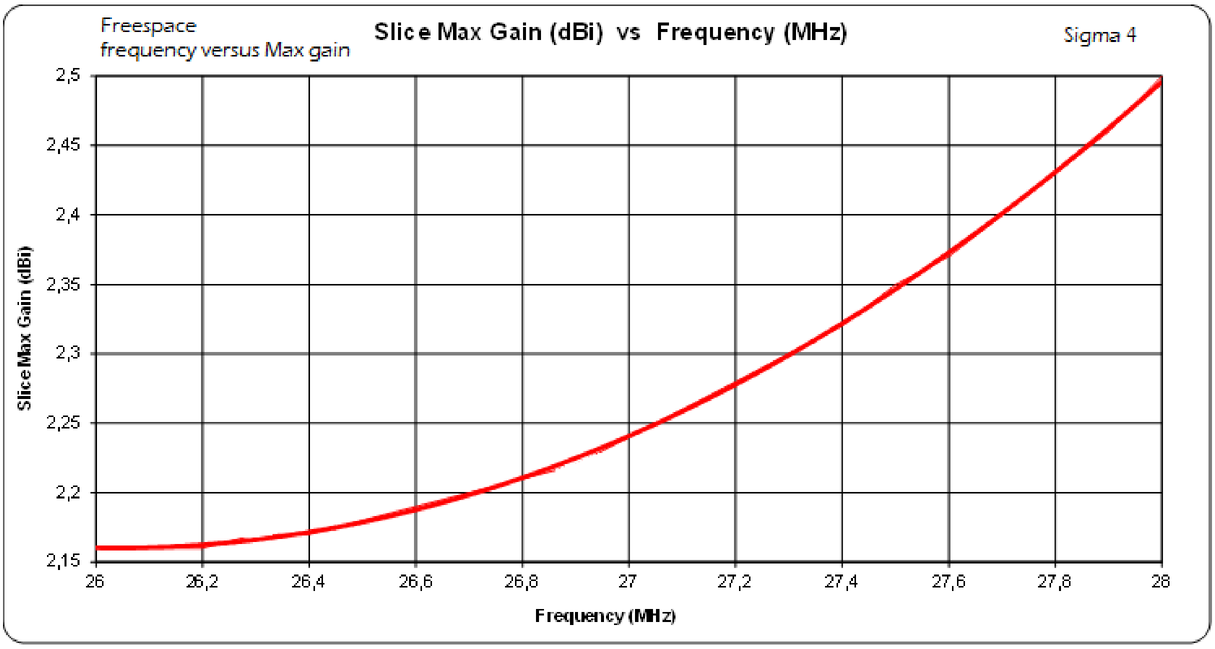


The “far field” > far field plot analysed using CST is providing 2,22 dBi



Above is the free space elevation plot provided using a NEC4 engine in Eznec Pro, again indicating 2,27 dBi.

Gain from a monopole antenna will vary with the frequency of operation.
If we analyse the gain provided from the Sigma IV versus frequency in free space we can provide :



The indication provided is that “maximum gain” from the antenna will become higher if we go up in frequency. Effectively making the antenna longer. That is what could be expected, as “longer” often means more gain.
It is important to realise these figures are provided in “free space”, there is a “catch” which we will discover in chapter 6.

Conclusion:
The Free space far field gain of the Sigma IV antenna is in the order of 2.2 to 2.5 dBi.

6 REASONS FOR GAINBUT NOT GAIN ITSELF ?

COMPARED TO OTHER ANTENNAS

So far we haven't provided an indication if the antenna could (really) outperform traditional antennas.
Traditional antennas for a CB user for example: a 1/2 wave or 5/8 wave end fed vertical.
As we know there are many who claim the antenna does.

Amongst these claim there are independent antenna user.
Being independent: It is not that strange to think: there must be something going on that is responsible for these good results.
Those lacking knowledge will be tempted to take the explanation from a manufacturer for granted including the gain figures in order to provide reason for the given "better performance".

That brings us to the questions:
What could be the reason the antenna has gained such a good reputation?

6-THE AVERAGE USERS:

Before we start comparing as we should do, there are some situations that could happen to the "average user"
Situations that could possibly influence the "average user" or their judgment.
Although it's not all scientific, they need to be mentioned as they could have an impact.

Just imagine a person:
Who just bought the antenna new and is going home with it.
Of course excited to find out how the antenna will perform.
That user (as often indicated on the forum) could have the impression:
A half wave vertical will produce the same gain as a dipole and the 5/8 wave antenna has more gain,
Some provide an indication that there is a "magical" . 64 λ that provides maximum gain.
And perhaps we are in a situation; where the new antenna will replace the old antenna on the same mast.

The above doesn't sound so strange, we need to realise however that just by "being" that person we already have mentioned several "pitfalls" that could influence judgement.

Including some "social" aspects:

1- We were "happy" in the car driving home with the antenna..
   We have obtained a "new" antenna; we spent "money" in order to expect improvement.
   The mind is "set" for "better".
2- The antenna is long…probably bigger than any antenna they have had in the past.
   That mechanical aspect "it is bigger" enforces the "mind" to think it is…it must be.
   And we are told very often "bigger is better".

And we have some "mechanical" aspects:

1- It is most likely to be replacing an old antenna.
   Perhaps the old one was not performing to its abilities anymore.
   For example: On the "VERON ANTENNE MEETDAG" an old large UHF Yagi was tested for gain.
   They noticed gain went up as soon as they start "polishing" the antenna.
2- And who knows: besides changing the antenna.. We also may have changed the coax ?

I can imagine someone to think:
The free space gain figure seems rather low, it is only in the order of 2.2 to 2.5 dBi.
From that perspective the advantages of the Sigma IV seems rather small.

Not only the social aspects or mechanical aspect can contribute, the antenna in a real situation could perform beyond what we expect from the indicated free space gain figure

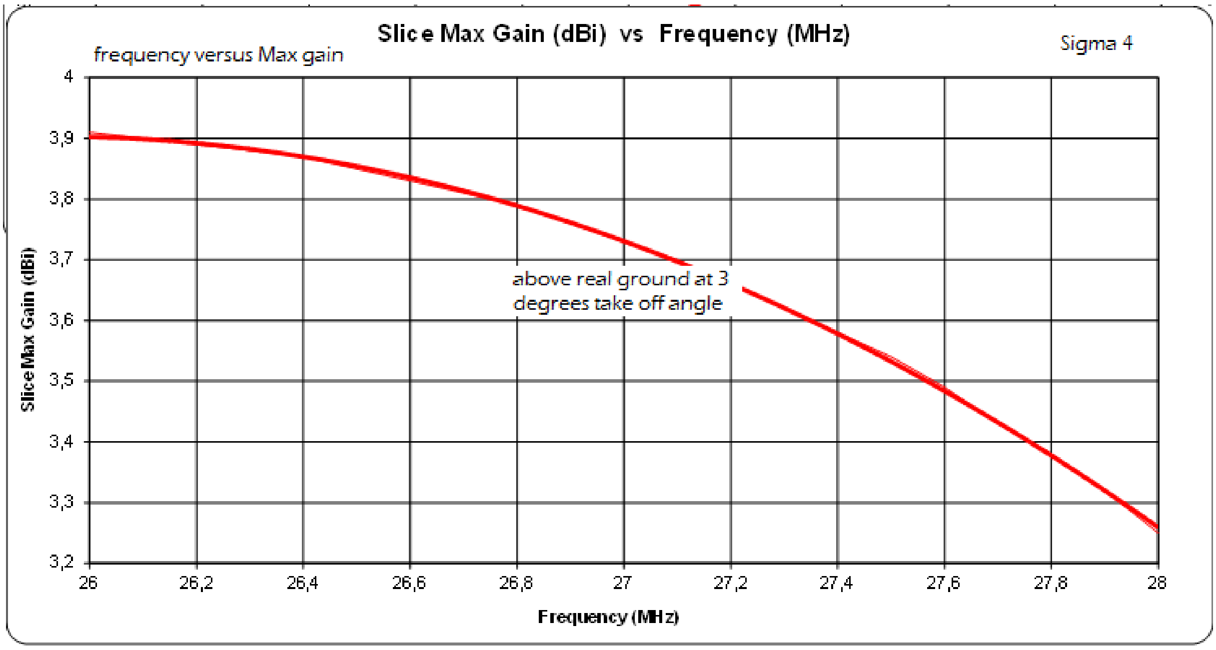
Again we are asking why?...why has the antenna gained such a good reputation ?
Perhaps there are other reasons that could be beneficial to the performance of the antenna?
Reasons that would not be so obvious at first sight but perhaps explain why there are those who have noticed several dB's difference when they compared the Sigma IV against another antenna.

And there is!

6- REASONS

First we will go back to the free space gain versus frequency plot (page 30)
But now, we will set the antenna in a real situation not in free space but above actual earth.

If we calculate the gain in a real situation and measure it at a low angle say at a 3 degrees take off angle,
We can notice:



This plot is opposite to the free space plot.
(Don't get the wrong impression from the gain figure, it is slightly higher as "ground reflections" will provide some additional "ground gain". This is also the case with any other antenna)

We know that in free space a long radiator will provide more gain.
But if we measure at a low angle we notice the gain provided under a low angle isn't going up.
From that we can draw the conclusion:
A longer radiator will produce more gain, but that gain will be pointed upwards.
And we all know: It is wise to focus on maximum gain at low angle instead.

Perhaps there are other interesting results if we start to have a closer look at a "real" situation.
Looking at the antenna and compare it to "real" other antennas we can discover quite a few amazing aspects!

If we ask anyone what could be the advantage of the Sigma IV most will provide the answer:

Well, its long…isn't it?
It is one of the longest antennas available and as we will find out: That is an important aspect.
Another one would be the performance we expect from other commonly used vertical antennas.

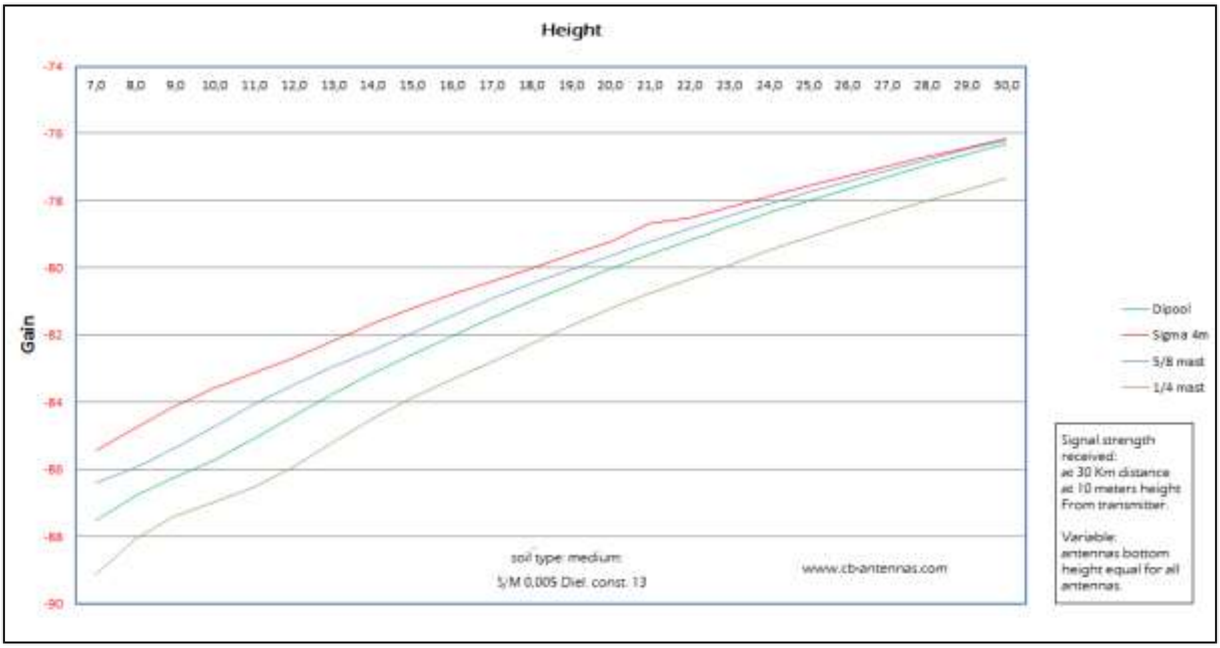
6-REAL AND IDEAL.

What if we measure the strength of the signal in real situation at a distant receiving location and compare those? Not only looking at a free space gain figure, not only looking at a far field plot.
But what will happen if we start analysing the total field, including the ground wave.

The first diagram is showing the signal strength in dB's
This is measured at a single point 30 Km away from the transmitting antenna.
At that location, it is measured at a height of 10 meters.
By doing so, we are trying to duplicate a real scenario:
Imagine: a person who is testing an antenna with a receiving stations at 30 Km.
That receiving station has his antenna situated at 10 meters height.

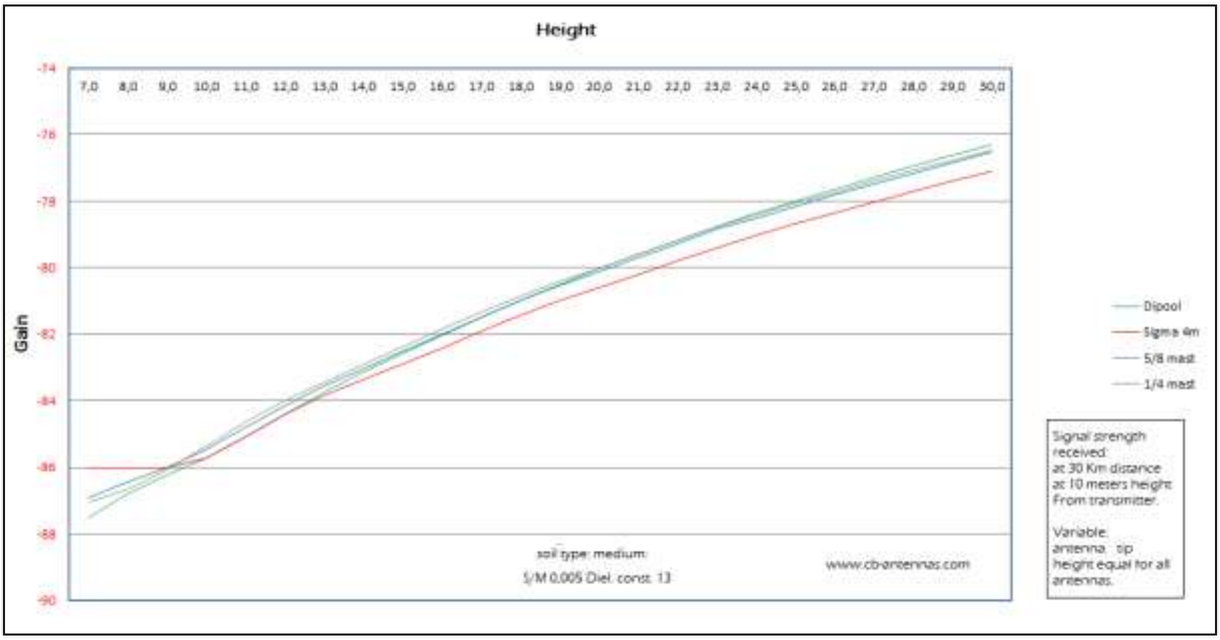
All antennas were "ideal" no losses and no other influence.
The soil type between the antennas was "medium".
The variable is the (antenna tip height) of the transmitting station, where each time the bottom of the antenna was kept equal…(top height of antennas not equal)

The height is -5,5 meter. (TOP HEIGHT DIPOLE = 7 m, ALL BASE = 1,5)



We notice that for an average user the Sigma IV is perfectly capable of "showing" gain up to several dB 's.
(Again: we have a "fixed" mast length, between 1,5 and 24,5 meters and are watching the strength of the signal change at a distant location for various antennas on that mast)

We also notice that the difference will become less with added height.



This second diagram (above) is showing the signal strength in dB's
This measured at a single point 30 Km away from the transmitting antenna.
At that receiving distance it is measured at a height of 10 meters.

All antennas again, were "ideal" no losses and no other influence.
The soil type between the antennas was "medium".
The variable is the mast height of the transmitting station.
Where each time the tip height of the antenna was kept equal.

Conclusion:

Antenna height is a factor that should not be underestimated.
Antenna height can make the difference between having several dB's advantage or not.

When placed at the SAME mast height and all antennas being ideal, the observer is most likely to notice several dB's of gain when he compares the Sigma IV against other commonly used verticals.
When placed at the SAME tip height the difference will not be that obvious.

So far we have used ideal antennas, no loss, no common mode current etc.
In a real situation sadly things are not “ideal”. Let us have a look at the other commonly used antennas:

6-COMPARED TO A HALF WAVE END FED VERTICAL:

We are expecting a half wave end fed vertical to provide 2,14 dBi gain, but is that true in all cases ?

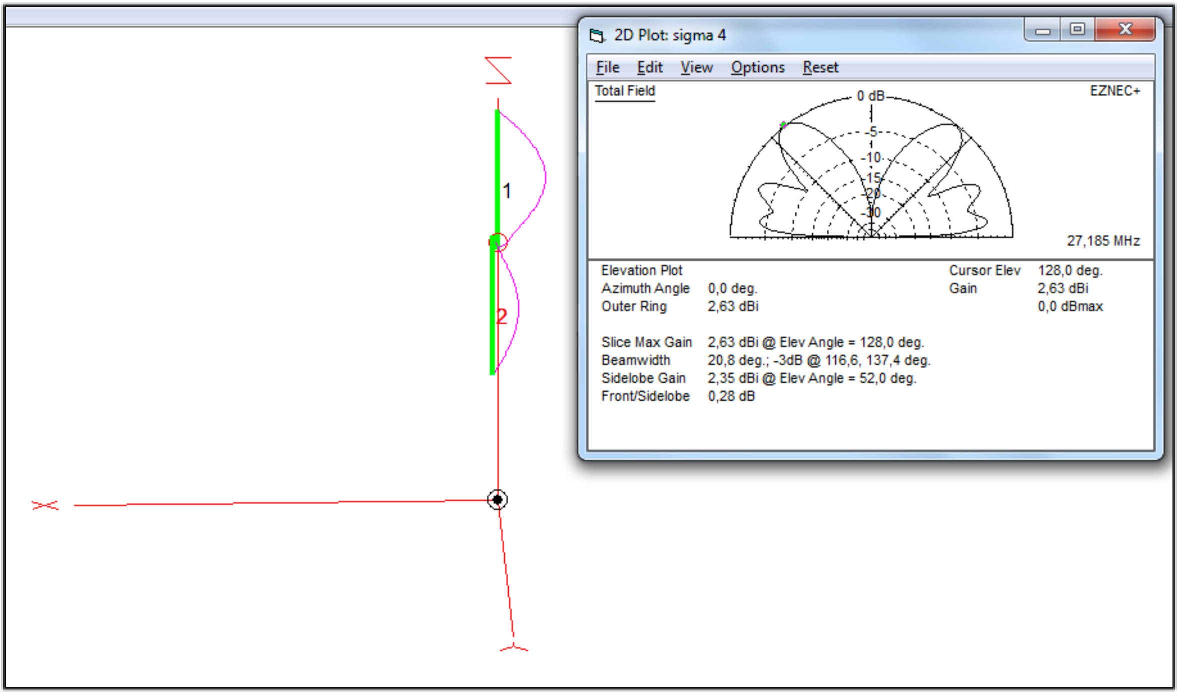
The 2,14 dBi gain mentioned is for a resonant half wave dipole without any losses.
The antenna we commonly use as a half wave is the half wave vertical end-fed.
In that case:
There always is some form of matching system (coil) and sadly not all are constructed that well.
Besides the possible “matching losses”, not all manufacturers use materials with “performance” in mind.
Some manufacturers (true in commercial FM broadcast applications as well) put the commercial aspect above performance.
So from a construction point of view we could have less performance than we initially would expect.

Another possible fact that could easily influence the performance of an end fed half wave antenna is the “basic” of the antenna.
It “lacks” the second part of the antenna. The more knowledge you will gain investigating antenna theory the more you will find out that symmetry is important. A half wave end fed vertical doesn’t have a “ground plane” .
That will cause common mode currents that could easily influence performance.

Most of the CB enthusiast will have heard about common mode currents, they have heard they can cause issues with RFI or SWR and some know they can influence the antenna pattern as well.
As soon as we have issues with RFI or QRM we can notice they are there.
The “thing” to remember is:
They can be there without the average CB user having an indication they are.

They can influence the antenna pattern even when you do not have issues with SWR and while you do not have issues with RFI or any other indicator.

An example:



Above is an example of a half wave end fed vertical. I have attached a "mast" next to it.
As we can notice the antenna pattern of the antenna is disturbed. The main lobe is pointing upwards instead of to the horizon where we actually want to have our main focus.
The "loss" at low angle is over 6dB compared to maximum performance at same height
The conclusion drawn compared to an half wave end fed:

It is very plausible there are many who have noticed an improvement compared to the half wave end fed vertical for several reasons. Not only the advantage of height of the Sigma but also the expected performance of the end fed half wave could very well not have been what we expected.

Those reasons are often of more impact than we would expect.

Important thing to remember is:

Although we think we have a good setup with our present setup, it could very well not be the case.
Do not take for granted your end fed half wave is always performing as we would like to, even though we have no indication there is something wrong.

6-HOW WILL THE ANTENNA FUNCTION COMPARED TO A 5/8 WAVE VERTICAL?

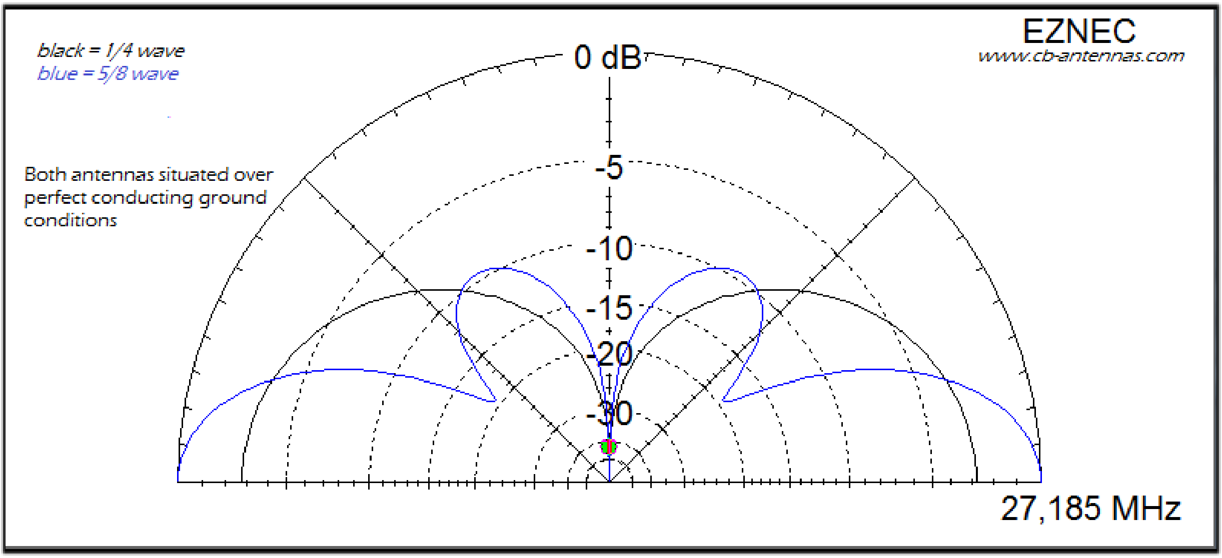
A lot of the "performing" errors mentioned in aspect to the end fed half wave are true for the 5/8 wave and could have a negative influence on the Sigma IV as well.
But besides those, there is a very stubborn myth about the 5/8 wave, that just will not go away.

As often with antenna myths there is some "truth".
Many of us have heard in the past: "well: theory is theory and practice is what is important!", however:

If theory and practice are not providing the same answer, it is either that theory is not understood or practice is wrong.

And the case of the 5/8 wave is certainly a case where theory is not always fully understood.
For example:

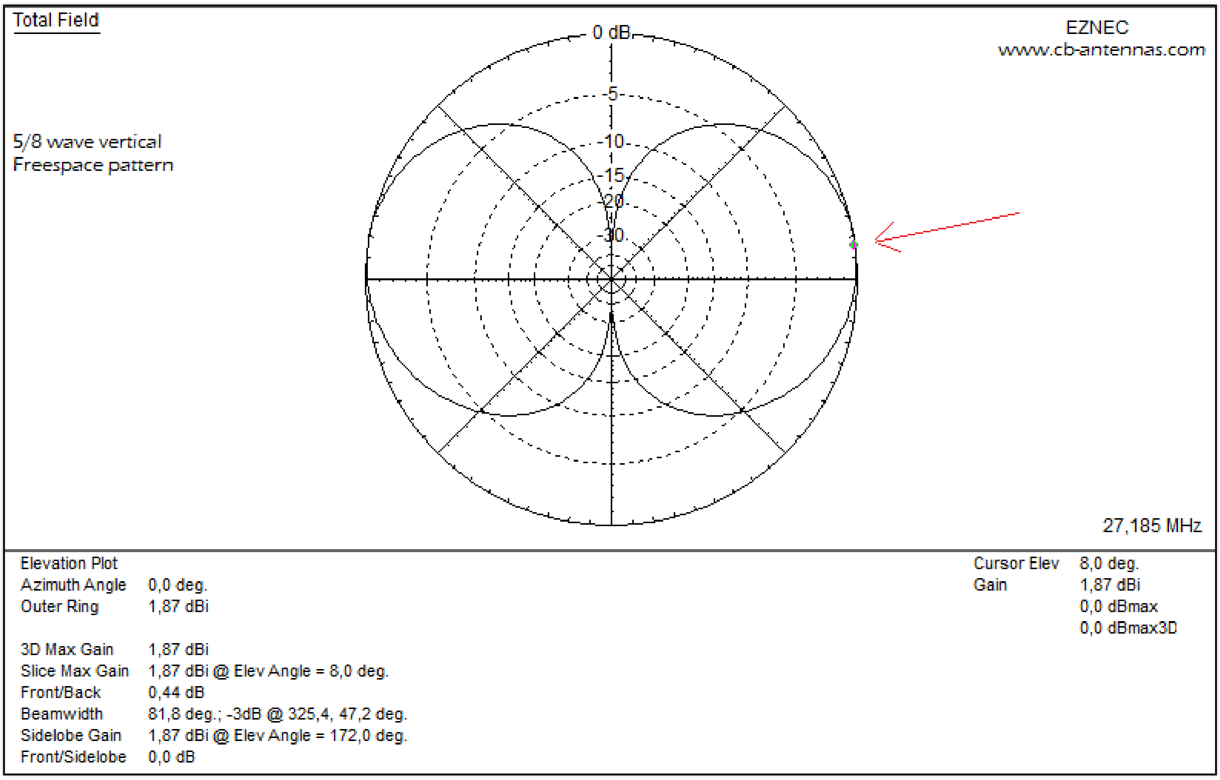
Most of us have the impression the 5/8 wave vertical has say 3dBi gain (give or take a bit)
Or we have seen a plot somewhere in a theory book that is similar to this one:



However, the gain and plots mentioned are based on an ideal theoretical world.
If we look outside, the earth is not a perfect conductor, far from it.

If we model a 5/8 wave in "free space" without a perfect ground we will find out the gain is not 3dBi.

And yes: ……There is our wake-up call…



The gain of a 5/8 wave vertical (and other antennas) will have a large influence because of "earth".
And that gain will vary with the distance from the earth.
At close range to the earth the 5/8 wave will outperform a dipole at same tip height.
Near the earth surface a 5/8 wave antenna is a known performer and that is where things go wrong.
Most theory books are based on either a perfect world or are orientated for the low band broadcasting world.

Something we don't realise nor read in theory books.

The fact is: The average CB user does not use the 5/8 wave close to the ground.
They will strive for the highest mounting location possible (for good reason).

As soon as we place the antennas at a reasonable height, the advantage of the 5/8 wave compared to a dipole becomes less. Above say 12...13 meters the dipole will actually start to outperform the 5/8 wave vertical (Same tip height) and the advantage of the dipole will increase beyond that height.

And now, we have a situation the average CB can relate to.
It is not that complicated for most to install an antenna at those heights.

It will be difficult to find a manufacturer who will tell you a 5/8 wave is not always providing maximum gain at low angle, and it is not providing say 3dB's over a 1/4 wave vertical in a real situation.

And that "myth" is backed-up by theoretical articles where most of them are all based on the infinite ground theory, or as mentioned are written with low band broadcasting in mind near a (created) "good" earth.

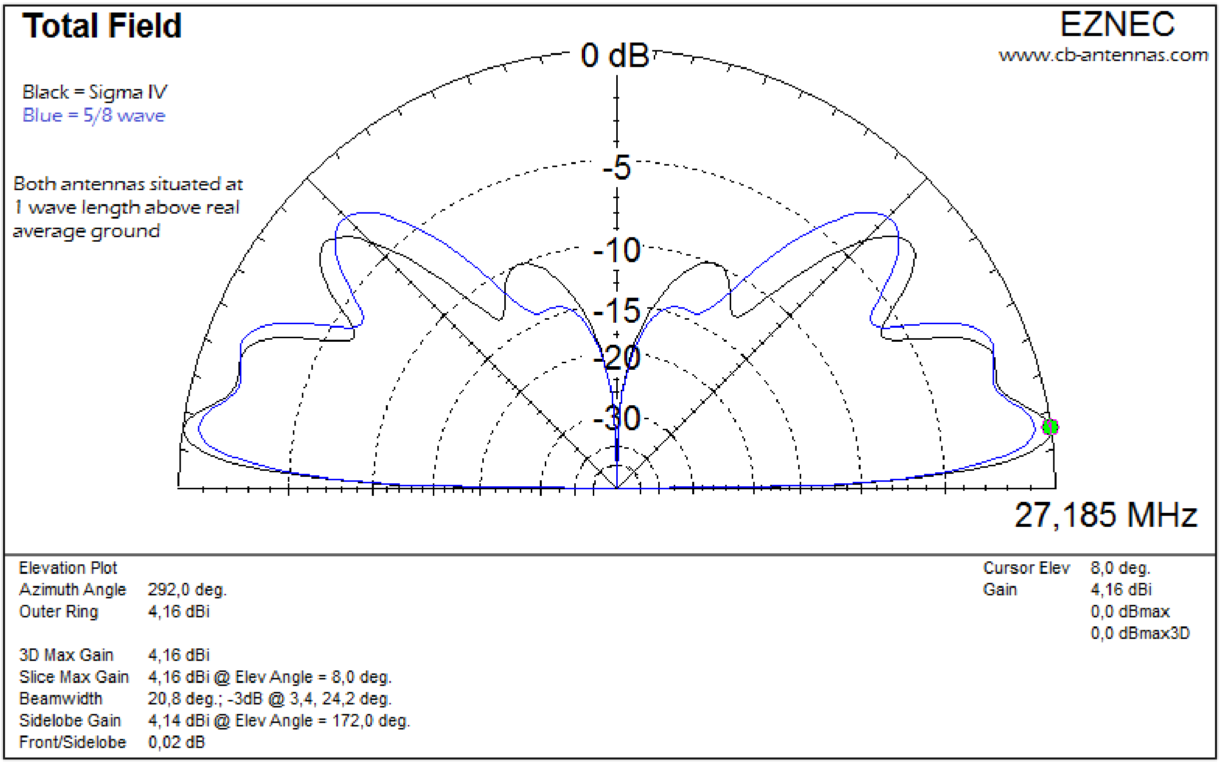
That is also the case with the claim made (page 6 point 7) about the ARRL open sleeve antenna.
It is a theoretical approach.

The "trick" they apply is to place the 5/8 wave over a "perfect" conductor.

Though there are situations where the infinite ground conditions are of interest, it is not for the average CB user.

It is obviously of far more interest from a commercial point of view not to tell what we can expect in a real situation. For that reason they tend to keep referring to the (theoretical) “infinite ground plane” gain figure.

If we compare the Sigma IV against the world’s best 5/8 wave without any losses both at the same mast the conclusion will be:



The Sigma IV can outperform a 5/8 wave vertical.

For as long as I know there has been an ongoing battle between the best 5/8 wave or.64 wave antenna. Please do not be fooled by how it looks, how expensive it is or what others have said about the “best” 5/8 wave antenna. If a person indicates his performance went up it only means his reference material was not functioning as he thought it was. We cannot construct a 5/8 wave antenna that performs beyond the capabilities of a 5/8 wave. We can only construct it in such a way that it is has less loss compared to others.

By looking at the above plot and the diagram provided on page 33, we notice one of the “claims” mentioned on page 6 (point6) is very plausible.(p6.6….*The gain will become more obvious at the distance horizon……*)

The “more gain at low angle” claim for a 5/8 wave vertical is without a doubt one of the best myths on 27 MHz and I am afraid it will remain that way for a long time.

6-REAL LIVE TESTING:

There is as much debate on how to measure antennas as there is about antennas themselves.
The initial thoughts were to write a second article to provide the measurement results gathered for the Sigma IV. However one could consider it a lack, if this article did not contain at least the findings of those results.
For that reason a future article will deal with: how to measuring antennas in real situations.
And for now we will refer to the results provided in this paragraph.

The measurements made were done using different measuring methods using data gathered from a spectrum analyser with a tracking generator and a relatively simple method using field strength measurements,

The "trick" with all measurements is to eliminate the data you do not want and be confident the data isn't influenced and you have an accurate method of verification.

Imagine that we are travelling and at the end of our journey we are provided with the distance and time we needed to get there.

Then you will be able to calculate how fast you have travelled, that sounds logical doesn't it?

But what if that distance is provided in a straight line?
And we actually went over a couple of mountains?
What about the conditions we were travelling in: Was it snow/rain/wind?
For sure that will affect the effective distance and therefore average speed.

And so is the case with measurements, we need to be confident we have the correct data and all the data and do not have any "side effects".

The antennas under test were:

J-pole
Sigma IV (copy)
Dipole
Sigma IV (with extra ½ wave on top)

- Same tip height
- RF choke attached
- Same mast (changed several times)
- Far within "far field region" (30 lambda)

During the test I was able to measure the gain difference in the J-pole pattern as such a pattern is not fully Omni directional, from that I have drawn the conclusion small changes were measurable.

The end result was: That gain from an antenna based on the principle of the Sigma IV was equal to that of the J-pole.

As mentioned, a future article will provide information.

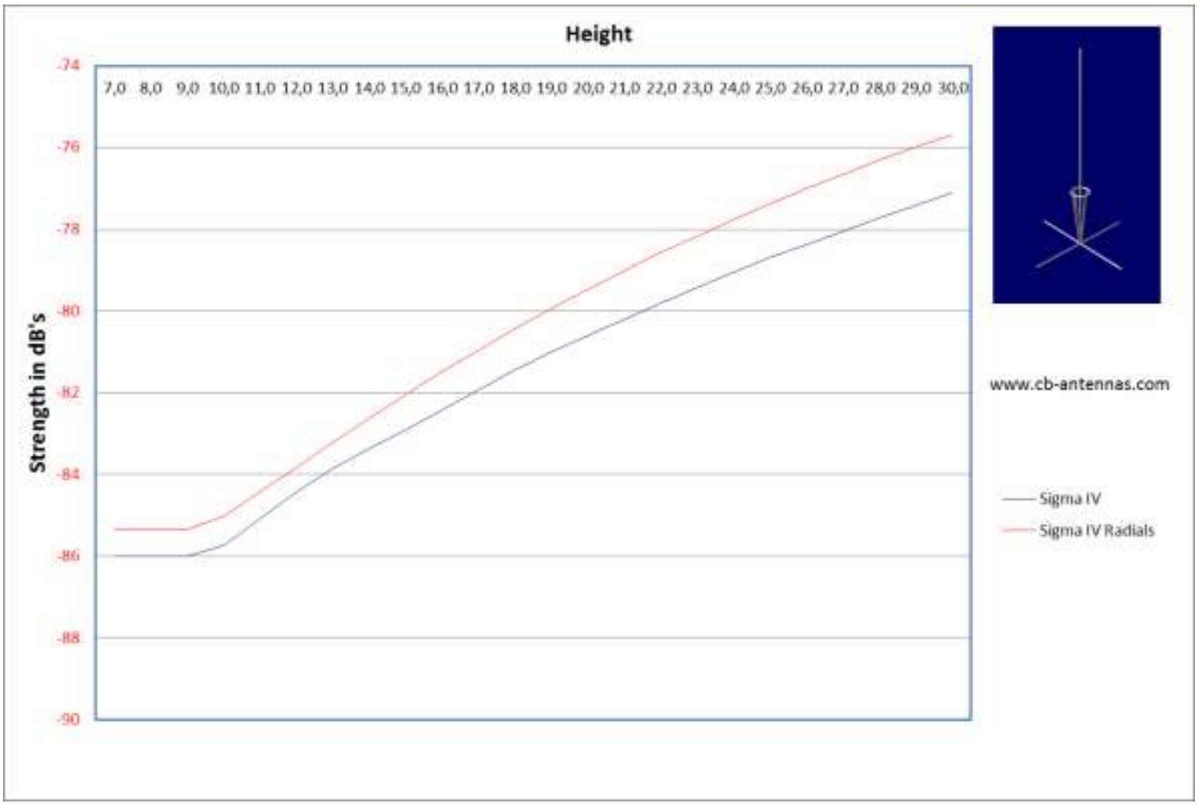
6-ROOM FOR IMPROVEMENT ?

We have already noticed that the antenna could very well be an improvement compared to others.
There are situation where that difference could become remarkably large. And in other situations the improvement will not be so noticeable.

We also noticed that in an ideal situation with added antenna height the difference will become less.
That is because of “ground”.
A possible improvement would be to improve the ground of the Sigma IV.
If we “eliminate” the mast and think of the Sigma IV being attached to a non-conductive mast.
And if we place a good RF choke at the bottom of the antenna and add 4 radials….to provide a “ground” for the antenna..

We can discover the signal strength received at a 30 Km away from the Sigma IV at a height of 10 meters can be improved by almost 2 dB depending on height.

Please notice that the difference between the two will become larger as we move the antenna further away from earth.



As mentioned, an RF choke is always advised. 5 turns with a 10 cm diameter (RG213) will provide a good choke to stop the coax from being a radiating part.

Another possible improvement would be to eliminate the gamma-match and direct feed the antenna.
As the cone acts as a transmission line there is nothing to stop us from finding the “50 ohms” resonant point, removing possible loss in that region…

7-Overall Conclusion:

During our search we were able to realise:

Antenna software based on MoM can model the antenna as long as we know what we are doing.
The results of (free) or relative cheap software compared to the best analysing software that will cost in the direction of $100.000 are equal.

We have discovered a lot of the claims made for the sigma IV are actually not out of proportion.
The interpretation of them on the other hand sometime is.

The antenna is capable of producing slightly more gain compared to a dipole.
The advanced software methods and real live testing have confirmed this

From a personal perspective, I was hoping we could find some additional gain and who knows…perhaps challenge theory! But after all work done it has convinced me there is not.
Each time the provided claims could be explained, nor could I find any proof there is a collinear effect as we know / imagine "collinear" to be.
It is a 1/2 wave radiator with a 1/4 wave matching stub, with a minimum amount of radiation from the cone contributing to the far-field.

With that said, the performance of the antenna is most likely to outperform others in an average situation.
From a "CB-user" point of view the antenna could be recommend.
It is most likely to outperform an half wave end fed antenna or a 5/8 wave antenna.
With the primary reason not being it has more gain:
But other factors it seems are responsible for the possible advantage, factors like:
The length of the antenna or the performance of the antenna in a real situation in combination with a mast and coax attached to it.
And the expectation we have from our reference antenna or the performance of it is often not what is expected.
That's an important point.

We need to realise we must be careful what to expect from the traditional vertical antennas we are using.

There still is a lot of room for an antenna manufacturer to improve the present day available vertical antennas.
This from both a mechanical and electrical point of view.

The ongoing "battle" of the best 5/8 wave or .64 wave is most likely not going to be the one that will result in the best signal for a CB enthusiast.

And although the Sigma IV is already a good performer, we have also found some grounds to further investigate to optimise the overall performance of the antenna itself.

The aim of this article was to provide further insight in the claims made for the Sigma IV.

We have tried to cover all aspects mentioned and hope the effort done could be an asset to those with interest about the Sigma IV antenna.

Warm wishes,

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7-Thank you !

To those active on the world wide dx forum for the intense work they have done in the past.
Bob, DB, Donald, Marconi and all others for keeping the debate alive and for always helping those with questions.

And to those who I consider experts, I am beyond grateful for the time they spend in the past answering questions and hope I can take advantage of that privilege in the future.

Thank you:

Arie Voors
Brian Cake
CST
FEKO
Roy W. Lewallen
Steve Hunt
Wim Telkamp

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13- Arie Voors
14- Brian Cake
15- C.A. Balanis

Appendix 1:
Patent Avanti

Appendix 2:
Model