# Inverted-V Log Periodic Antenna

## *Evaluation and Expected Performance*

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**Abstract** : An Inverted-V Log-periodic dipole antenna (LPDA) has been designed as an alternative to the Sabre 608 Log-periodic antenna. This new antenna consisting of wired elements, is more robust than the current antenna due to its well support design, light in weight and presents minimal wind loading. A scaled model of this new antenna structure was analysed in NEC 2, then practically constructed for comparison studies. A new sub-bandwidth structure concept, which has been introduced and implemented for the first time in this design, has shown a significant improvement in the overall performance of an Inverted-V LPDA.

## 1 Inverted-V LPDA Antenna

Having discussed in the previous paper [7], Inverted-V LPDA design provides some advantages over that of the conventional LPDA as such it is a well supported one tower structure that is suitable to operate in severe weather conditions; can cheaply be constructed from wire; simplifies installation process; minimises wind resistance; sustains constant electrical height above ground; allows longer boom length without significant construction limitations. The previous modeling results has shown that the inverted-V LPDA antenna behaves very well over the design bandwidth.

Even though, the use of Inverted-V dipole as elements in LPDA has broaden its operating bandwidth and is physically shorter in term of horizontal spacing, however, the Inverted-V dipole produces lower gain in comparison to normal dipole. The gain of an Inverted-V LPDA is approximately constant across this broadband, but tends to fall off at the higher end of the frequency band (approximately 1.5 dB variation). Reduction in gain can easily be explained by looking at the current distribution on the array in the high frequency region. Generally, there are not enough resonant elements contributing to the active

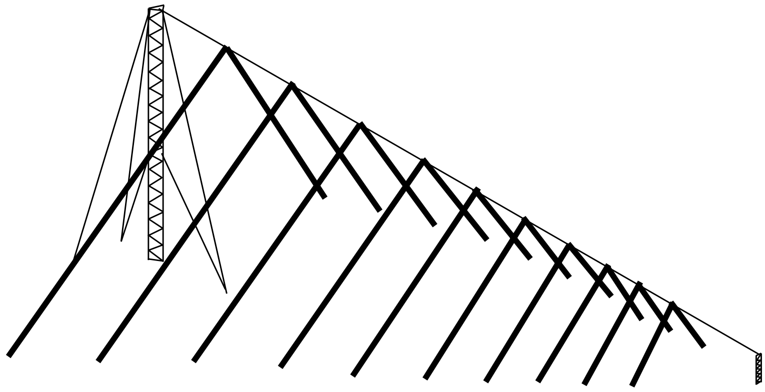



Figure 1: An Inverted-V LPDA

region to maintain the constant gain at the higher end of the frequency band, whereas at the low frequency end, better gain is attained due to the contribution from midband region. To increase the gain at the high frequency end, the conventional approach would require us to add extra high frequency elements [5]. Indeed, it was found that if the extra elements were added, a constant gain can be maintained throughout the broadband. However, this solution is not very practical, nor economical.

## 2 Sub-Bandwidth Concept

The usual approach in designing LPDA is to select an appropriate set of values for the scaling and spacing factors which would produce a suitable LPDA as specified. The choice of scaling and spacing factor determines the resultant number of elements on array, boom length and taper angle. Because each element (and its environment) is progressively scaled, a too high value of scaling factor will give rise to rather a large, high density element array and expensive to construct. On the other hand, a large spacing factor lengthens the boom length, lowers the VSWR and exhibits inconsistent performance over the broadband. Instead of designing LPDA array as a whole, we can break the design bandwidth ($B$) into a number of sub-bandwidths (for example $B_1, B_2$). Mathematically, this concept holds true as long as

$$\begin{aligned} B &= B_1 B_2 \\ &= \left\{\frac{f_{max1}}{f_{min}}\right\}\left\{\frac{f_{max}}{f_{max1}}\right\} \\ &= \frac{f_{max}}{f_{min}} \end{aligned}$$

This method has proven to be useful because it allows us to closely concentrate on designing a small section of the array over a narrower operating bandwidth. Once all of these sub-bandwidth sections have been designed, they are then joined together to make up a complete design of a LPDA. The key success to this design is based on the choice of suitable sub-bandwidth regions. It is not recommended to have too abrupt a change from one region to the next because, from observation, sudden change in structural dimensions disrupts the smoothness of the transition of the active region as operating frequency varies. In the worst scenario, the LPDA under design may loose its frequency independent characteristics, severely affecting the radiation pattern and its VSWR may rise or highly fluctuate due to variation of current distribution as frequency changes.

As illustrated on figure 2 below, the sub-bandwidth regions were designed with a different set of scaling factor $(\tau_0, \tau_1)$. Each sub-array consists of small number of elements, but were all carefully chosen so as to consistently maintain a constant, high gain over the designated sub-bandwidth. For the over-lapping region, a new set of scaling factor was used to blend the two sub-bandwidth regions together. It was found that the design parameters chosen for this region are very important. To ensure a smooth transition of the active region throughout the array bandwidth, we must carefully consider the spacing distance between the last element of the first sub-array to the first element of the second sub-array as well as their lengths (with respect to their resonant frequency). Otherwise, radiation from each sub-bandwidth region may disturb its neighbouring region, hence, causing undesired radiation. This is where the simulation tool such as NEC 2 becomes useful. We can compute different combinations to see the resultant effect before making our final choice of the design parameters in all regions.

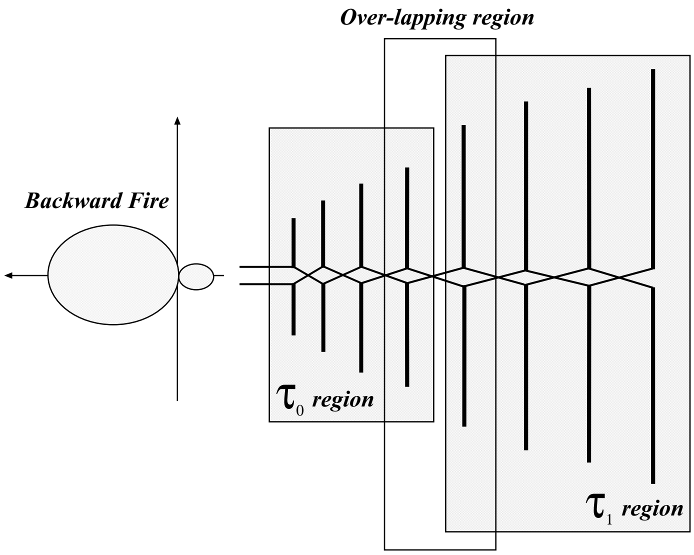



Figure 2: Sub-Bandwidth Concept in LPDA Design

# 3 1/100 Scale Model Design

Based on our sub-bandwidth concept, a prototype Inverted-V LPDA was designed for the frequency band covering from 1.0 to 2.0 GHz. It consisted of 10 Invert-V dipole elements, its boom length is approximately 13.2 centimeters (where the largest spacing distance among the elements is 2.4 centimeters).

Within the structure, the array is divided into 3 different regions. The first region covers the lower frequency end, whose scaling factor is 0.9. A low concentration of elements in this region and each element is largely spaced apart. It produces a moderate gain level on its own.

The second region has a scaling factor of 0.87. It was designed with a higher concentration of elements (4 elements) and all elements are well chosen to provide a good dimensional matching with its neighbouring regions while maintaining an excellent gain value. This is critical because its performance is used to support both the lower and higher frequency regions.

The last region covers the high frequency portion. Theoretically, it consisted of 4 elements, however, its largest element falls into the second region. A scaling factor of 0.9 was chosen for this region. All element are closely spaced to provide an adequate gain figure.

It was noticed that deterioration of performance at the two extreme frequency ends is the most common problem in LPDA design. The sub-bandwidth method helps to remove this difficulty. By having chosen appropriate design parameters for each region, the final mutual interaction between them supports one another to maintain a good constant gain and consistent radiation pattern throughout the design bandwidth.

Figure 3: 1/100 Scale Prototype Inverted-V LPDA

The simulation results from NEC 2 indicates that this Inverted-V LPDA is capable of producing an almost constant gain greater than 10.5 dB over the specified bandwidth. Figure 4 shows the gain figure within the three sub-bandwidth regions. There is a drop of gain between the transition between the second and third regions. This minor problem arises from a slightly poor choice of sub-bandwidth division. It is easily solved by extending the second region to cover up to 1.67 GHz (presently cut off at 1.625 GHz). Plots of the current distribution of Inverted-V LPDA at any frequency on its operating bandwidth predicts that at least a minimum of 4 resonant elements contribute to the active region at any one time. No presence of end-effect was found because most of the

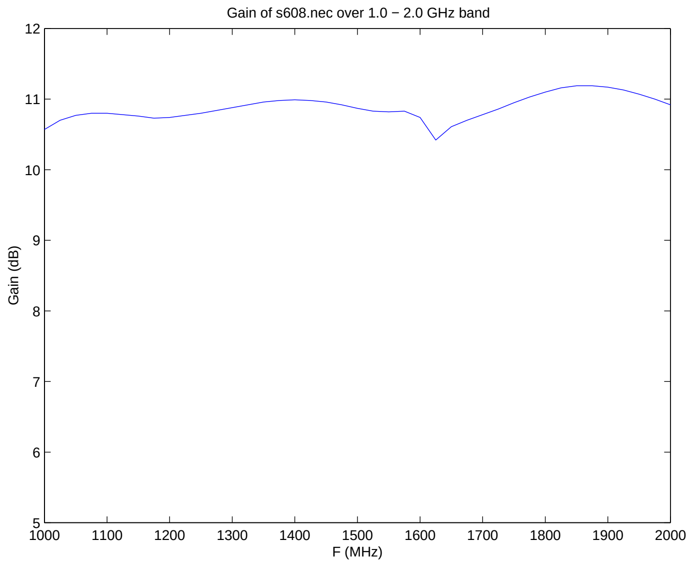



Figure 4: The Gain of Scale Prototype Inverted-V LPDA

current flowing on array was well exhausted by the resonant portion, hence, no leakage of power passed beyond the active region. Inherently, a VSWR figure of well below 2 : 1 ratio was obtained over the frequency region of interest.

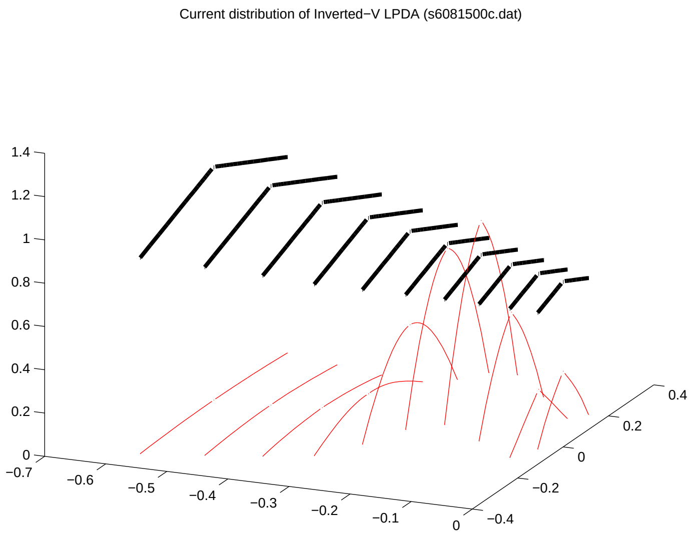



Figure 5: The Current Distribution of Scaled Model at 1.5 GHz

With the assistance of the Griffith University's antenna laboratory, the radiation pattern of the scaled prototype was measured at some particular frequencies in the design bandwidth. Most of the elevation and azimuth patterns agreed well with the simulation results. It was found that due to difficulties in

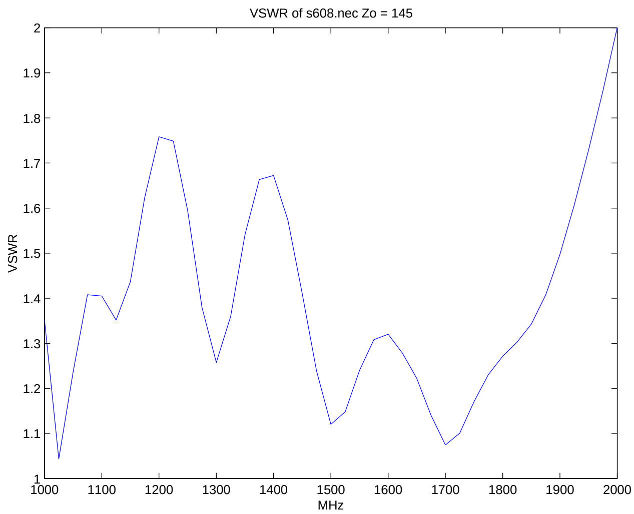
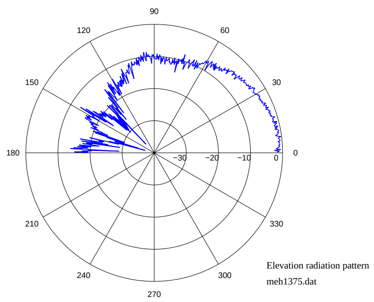


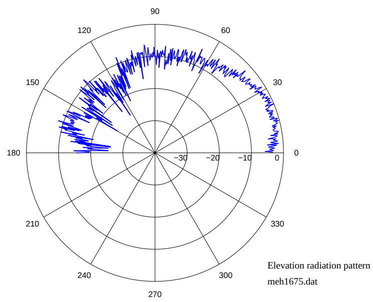

Figure 6: The VSWR of Scale Prototype Inverted-V LPDA

the construction process such as precision of dimensions, feeding technique and the conductivity of the scaled model, it was not possible to perfectly match the measured results to the modeling results. The asymmetry nature of the SMA connector used caused the radiation pattern to skew at some angles. Also, radiation patterns measured are very sensitive to the arrangement of the feedline.

Apart from some minor construction problems, this practical model has demonstrated that it is possible to design Inverted-V LPDA using the sub-bandwidth method. The performance of Inverted-V LPDA satisfies the expected specifications. Its radiation characteristic is relatively constant; a good gain level is maintained throughout the broadband and its VSWR falls below 2 : 1.

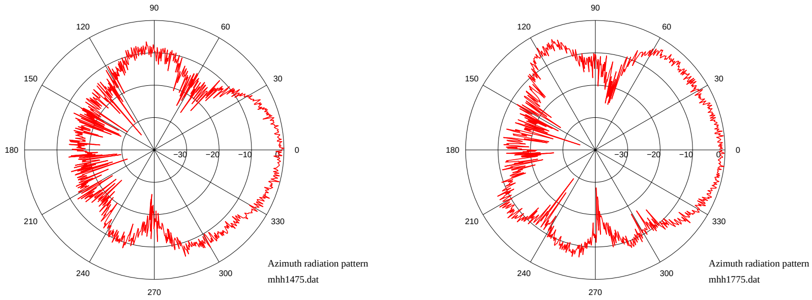



(a) 1375 MHz




(b) 1675 MHz

Figure 7: Elevation pattern of Inverted-V LPDA




(a) 1475 MHz (b) 1775 MHz

Figure 8: Azimuth pattern of Inverted-V LPDA

## 4 Conclusion

A different approach in designing LPDA has brought about a significant improvement in performance over that of the conventional designing procedure. The Inverted-V LPDA displays very good performance over the desired bandwidth. The wire structure is much more reliable and requires minimal maintenance. So far, no modification or any optimisation on this type of LPDA has been conducted. Current investigation on using sub-bandwidth shows many promising results. It may well be the next version of HF antenna of SuperDARN.

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