International Journal of Engineering & Technology, 7 (4.36) (2018) 1291-1294

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Design and Analysis of The IFA Bandwidth Enhancement for 639 MHz UHF Channel

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Abstract

Bandwidth characteristic enhancement of the antenna is engaging and challenging problems for antenna engineers. The design of the 639 MHz frequency of the low-profile inverted F antenna (IFA) on a finite conducting plane proposed and its characteristics are analyzed numerically. The IFA is typically a narrowband antenna, due to the bandwidth enhancement the antenna parameters are considered. When the size of the conducting plane is 115 mm by 230 mm, the return loss bandwidth (-10 dB) becomes 2.4 % and the gain becomes 6.58 dB. The results found that when the height of the antenna reduced the return loss bandwidth becomes narrower. However, the return loss bandwidth can be improved by extending the length of the short stub. The gains of IFA are more than 6.5 dB in all the calculation conditions. This means that the gain characteristics are not significantly affected by variations in short stub length, the antenna heights and the size of conducting plane. The results show that by extending the height of the antenna and enlarge the size of the conducting plane improved the bandwidth enhancement of the IFA. The proposed inverted F antenna is promising for the UHF channel receiver.

Keywords: *Bandwidth Enhancement; Inverted F Antenna; Method of Moment; Short Stub; WIPL-D*

1. Introduction

A simple and compact antenna design with good performance nowadays still becomes the object of interest for antenna engineers, especially in bandwidth characteristic enhancement. As long as the dimensions of the antenna have no apparent way to install, therefore the light and small antenna are needed. One possible design that met with those requirements is a low-profile inverted F antenna. A modification of the transmission line antenna or bent monopole antenna (inverted L antenna), with an offset feed called The Inverted F Antenna (IFA) which provides adjustment for the input impedance. The antenna geometry produced resembles the letter F rotated to face the ground plane [1-4]. The element of inverted F antennas originally evolved from the folded L antenna with the additional short stub [5-7]. The inverted L antenna can be seen as a bent monopole and by bending the monopole results in a reduced size and low profile [8]. The monopole is the most widely used antennas for wireless mobile communication systems. Monopole arrays may be the most common antenna elements for portable devices, such as cellular telephones, cordless telephones, etc. [9-11]. By using equivalent transmission line models both the inverted L and the inverted F antennas can be analyzed. The radiation patterns in the two principal planes are not much different from monopole [8]. One of the authors has examined the unbalanced fed IFA for 2.45 GHz Wireless Communication System and the results show the return loss bandwidth less than -10 dB becomes 3.67 % and gain is 4.15 dB [12]. Including, the conventional base fed IFA analyzed numerically and its characteristics compared with those of the unbalanced fed inverted L antenna. The results show as the antenna with return loss bandwidth of less than -10 dB becomes 15.92% besides the gain is 3.94 dB [13]. In this work, the proposed inverted F antenna on a finite conducting plane designed and analyzed numerically. The bandwidth enhancement of IFA analyzed by extending the height of the antenna while adjusting the size of conducting plane. The WIPL-D electromagnetic simulator based on the Method of Moment used in the numerical analysis. Due to the antenna characteristic improvement such as radiation pattern, input impedance, return loss bandwidth and gain, the lengths of the horizontal element are optimized [14-16].

2. Antenna Structure

Fig. 1 shows the structure of the proposed IFA mounted on the conducting plane. The size of the conducting plane is *pxp+pxm* by *pyp+pym*. The radius of the outer conductor is 1.095 mm and the inner conductor is 0.255 mm. An inner conductor from a semi-rigid coaxial cable extended from the end of the outer conductor, this antenna is excited at the end of the outer conductor (feed point). The height *h* of the antenna is from 23 mm to 62 mm, and the length *Ls* of the shorted antenna element is from 15 mm to 31 mm. While the length *L* & *L1* of the horizontal elements are optimized. The size of the conducting plane is considered as 70~115 mm by 170~270 mm. Numerical analysis of the simulation results of the designed antenna to optimize all critical parameters such as return loss bandwidth with -10 dB at the design frequency of 639

MHz. The length L & $L1$ of the horizontal elements adjusted so that the impedance matching 50 Ω at the center frequency obtained. The radiation pattern characteristics, both components E_θ and E_ϕ analyzed in order to determine the directive gain with its pattern. Moreover, antenna parameters, its size, length, height are optimized to obtain the best design. The wavelength λ at 639 MHz is 469.48 mm.

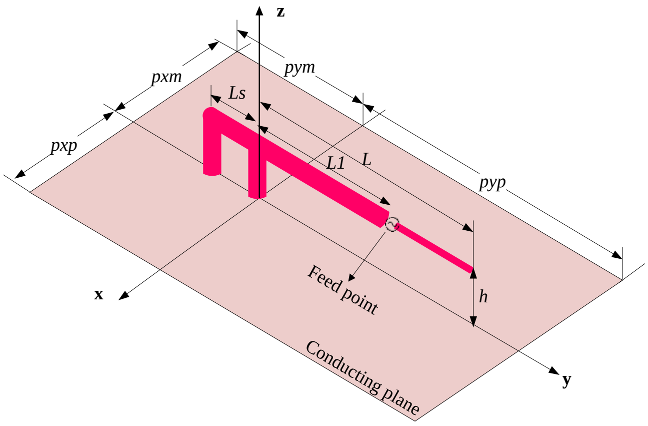


Fig. 1: Structure of the proposed IFA

The effective length of IFA is *Ls*+*L*+*h*, where *h* is the height of IFA. The resonance condition then is expressed by equation (1).

$$Ls + L + h = \frac{\lambda}{4} \tag{1}$$

Where λ is desired wavelength. As $\lambda = \frac{c}{f}$, where *c* is the speed of light and *f* is the desired frequency of IFA [17]. Thus, expressed in equation (2).

$$f = \frac{c}{4(Ls + L + h)} \tag{2}$$

3. Result and Discussion

The IFA performance was analyzed by adjusting the antenna parameters such us heights (*h*), short stub (*Ls*), horizontal element (*L* and *L1*) and size of conducting plane (*px* x *py*). The antenna heights (*h*) are investigated at 23 mm, 30.7 mm, 38.3 mm, 46 mm, 53.7 mm and 61.3 mm. The input impedance matches at the designed frequency by optimizing the lengths of the horizontal element (*L* and *L1*).

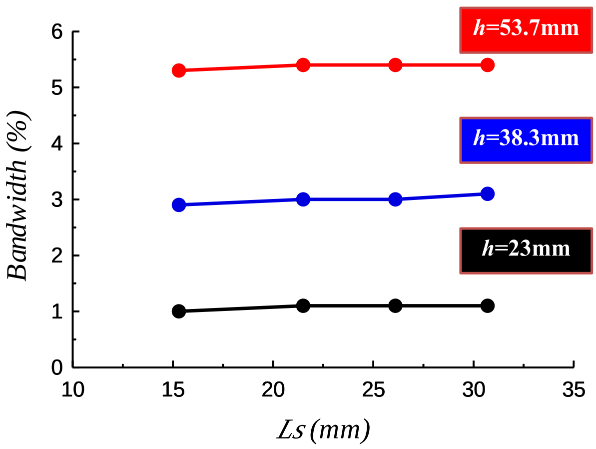


Fig. 2a: Comparison the return loss bandwidth of IFA with different *Ls* at 639 MHz.

Fig. 2a and Fig. 2b show comparison return loss bandwidth and gain with different height at 639 MHz by investigating on the length of short stub (*Ls*). The *Ls* adjustments do not significantly affect the bandwidth enhancement and the gain characteristic. The results show that by extending the height of the antenna the bandwidth enhancement of IFA is performed, while the gain reduced.

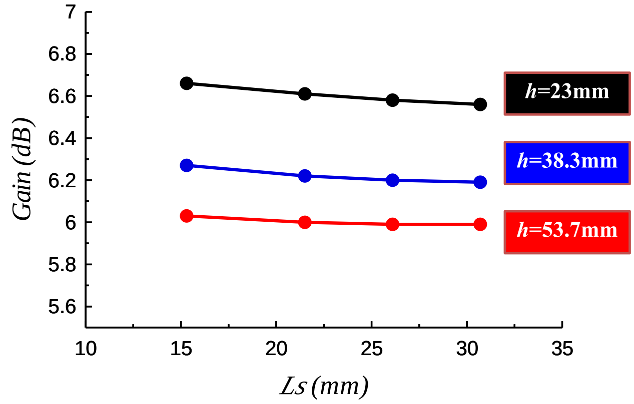


Fig. 2b: Comparison the gain of IFA with different *Ls* at 639 MHz.

Table 1: Return Loss Bandwidth and Directive Gain of IFA for Different Size of Conducting Plane at 639 MHz.

Ls	L	L1	pym	pyp	Return Loss Bandwidth			Directive Gain at 639 MHz
[mm]					f-low (MHz)	f-high (MHz)	%	
h=23mm								
15.3	186.7	155.0	53.6	200	635.2	641.84	1.0	6.66
21.5	180.8	149.2	59.8	200	635.6	642.4	1.1	6.61
26.1	177.0	144.9	64.4	200	635.5	642.5	1.1	6.58
30.7	173.2	140.9	69.0	200	635.5	642.6	1.1	6.56
h=30.7mm								
15.3	177.2	136.4	53.6	186.4	633.6	644.7	1.7	6.62
21.5	171.8	130.1	59.8	186.4	633.3	645.0	1.8	6.55
26.1	168.0	126.4	64.4	186.4	633.1	644.9	1.8	6.55
30.7	164.5	122.8	69.0	186.4	633.1	645.1	1.9	6.49
h=38.3mm								
15.3	168.8	120.8	53.6	176.4	631.4	647.1	2.5	6.54
21.5	163.6	115.0	59.8	170.2	631.5	647.4	2.5	6.54
26.1	160.1	112.0	64.4	165.6	631.3	646.9	2.4	6.55
30.7	156.6	108.9	69.0	161.0	631.5	647.0	2.4	6.58
h=46mm								
15.3	161.7	106.5	50.0	168.0	629.2	649.5	3.2	6.48
21.5	156.2	103.5	52.0	162.0	630.0	649.0	3.0	6.52
26.1	152.8	99.8	56.0	160.0	629.6	649.0	3.0	6.52
30.7	149.3	96.5	58	158	630.1	649.3	3.0	6.54
h=53.7mm								
15.3	153.2	90.4	50.0	168.0	632.2	660.2	4.4	6.38
21.5	150.2	88.5	52.0	162.0	626.9	652.8	4.1	6.4
26.1	144.8	82.3	56.0	160.0	632.8	660.5	4.3	6.42
30.	141.	79	58	158	632.8	660.4	4.	6.44

7	5						3	
h=61.3								
15.3	146.4	75.6	50.0	168.0	632.2	668.1	5.6	6.21
21.5	141.6	72.2	52.0	162.0	632.5	667.3	5.4	6.26
26.1	138.5	69.2	56.0	160.0	638.1	675.5	5.9	6.26
30.7	135	66	58	158	637.6	674.4	5.8	6.28

Table 1 shows the results of calculated return loss bandwidth -10 dB and the directive gain of IFA with the different size of conducting plane with *pxp* = *pxm* = 57.5 mm at 639 MHz. When the height of the antenna reduced the return loss bandwidth becomes narrower, while the gain characteristics do not significantly affect with the changes of the height, the length of the short stub and the size of conducting plane. The calculation result indicates that the height affects total length of the horizontal element, the antenna bandwidth, and size of conducting plane associated with the current distribution of the conducting plane. Table 2 shows the results of calculated return loss bandwidth -10 dB and gain of IFA with the same size of conducting plane with *pxp* = *pxm* = 57.5 mm at 639 MHz. The antenna heights (*h*) are investigated at 23 mm, 38.3 mm and 53.7 mm. The bandwidth enhancement does not affect significantly by adjusting the *Ls*. Extending the height and the length of *Ls* will reduce the gain. The calculation results indicate that by extending the height of the antenna and enlarge the size of the conducting plane the bandwidth enhancement of the IFA is achieved.

Table 2: Return Loss Bandwidth and Directive Gain of IFA for Same Size of Conducting Plane at 639 MHz.

Ls	***L***	***L1***	***pym***	***pyp***	**Return Loss Bandwidth**			**Directive Gain at 639 MHz**
[mm]					**f-low (MHz)**	**f-high (MHz)**	**%**	
h=23mm								
15.3	186.7	155.0	53.6	200	635.2	641.84	1.0	6.66
21.5	180.8	149.2	59.8	200	635.6	642.4	1.1	6.61
26.1	177.0	144.9	64.4	200	635.5	642.5	1.1	6.58
30.7	173.2	140.9	69.0	200	635.5	642.6	1.1	6.56
h=38.3mm								
15.3	169.5	116.8	53.6	200	630.1	648.9	2.9	6.27
21.5	164.4	111.0	59.8	200	629.7	648.9	3.0	6.22
26.1	160.8	107.6	64.4	200	629.8	649.1	3.0	6.2
30.7	157.4	103.8	69.0	200	629.9	649.4	3.1	6.19
h=53.7mm								
15.3	153.4	84.4	53.6	200	631.9	665.7	5.3	6.03
21.5	148.6	79.0	59.8	200	631.8	666.2	5.4	6
26.1	145.2	75.0	64.4	200	632.2	667.0	5.4	5.99
30.7	142	72	69.0	200	632.1	666.7	5.4	5.99

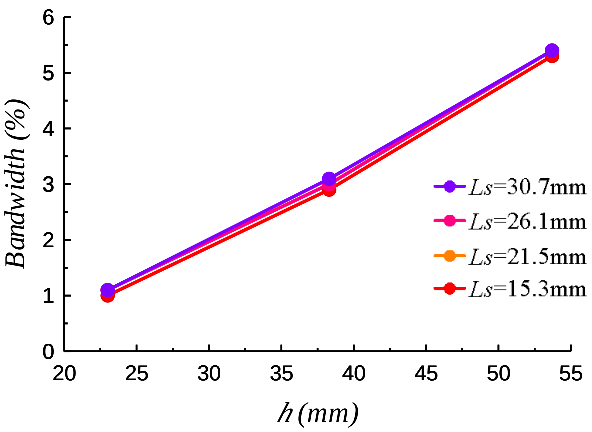


Fig. 3: Comparison the return loss bandwidth of IFA with different *h* at 639 MHz.

It is well known that the IFA performance parameters, such as efficiency and bandwidth enhancement depend on the antenna height, while the resonant frequency of the antenna primarily depends on the antenna length. As proven on [18], it was shown that adjusting the height can be used to increase the bandwidth. Fig. 3 show comparison return loss bandwidth with different length of short stub (*Ls*) at 639 MHz by investigates on the height of the antenna. The graph shows that the antenna bandwidth has significant achievement by increase the antenna height.

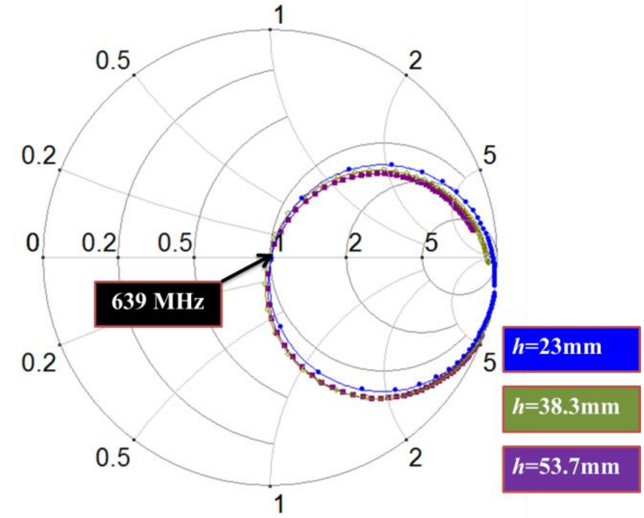


Fig. 4a: Impedance matching

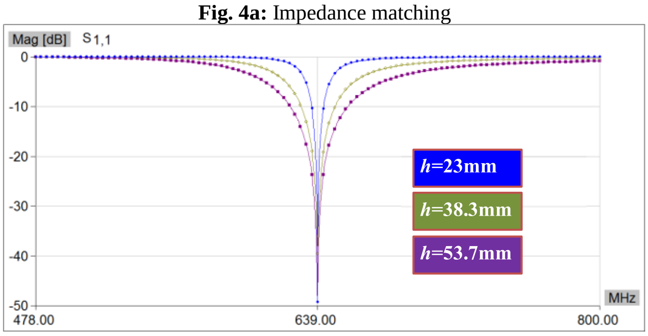
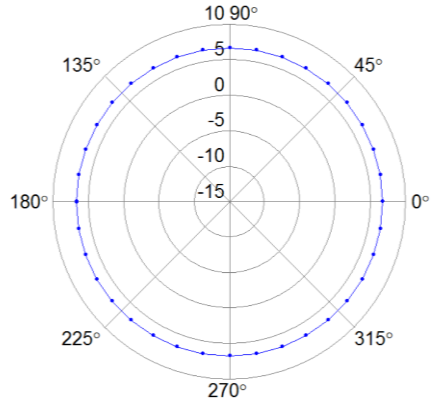


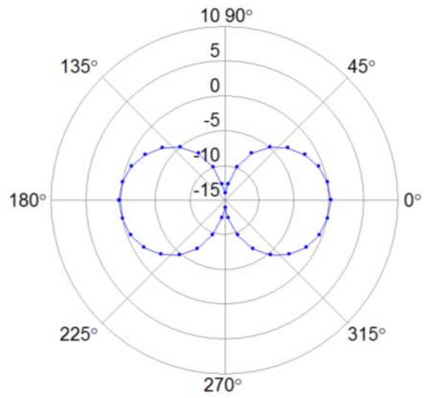
Fig. 4b: S-Parameter

An important part of microwave engineering is impedance matching of one circuit to another in order the impedance within two related circuits or two media can operate properly. To achieve this match, extra circuits within the two elements of the original circuit probably needed. In this proposed antenna matching circuit is not needed. It was shown [19] that by adjusting the length of the antenna automatic impedance matching can be obtained.

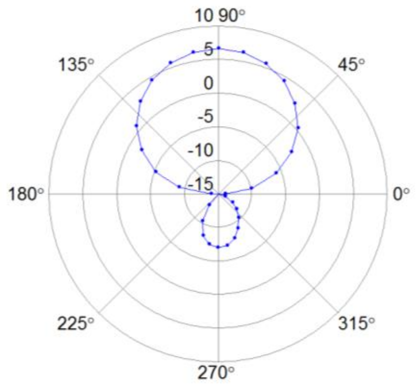
Fig. 4a shows the input impedance matching characteristic. The impedance matching at the center frequency is obtained by optimizing the length of horizontal elements *L & L1*. While Fig. 4b shows the calculation results by extending the height of the antenna, the bandwidth enhancement of IFA achieved. The input impedance and S-parameter results of IFA are investigated between various heights and the same length of short stub, h = 23 mm and Ls = 21.5 mm, h = 38.3 mm and Ls = 21.5 mm, h = 53.7 mm and Ls = 21.5 mm. Fig. 5 shows the computed electric field radiation pattern of IFA (E_θ and E_ϕ) with height h = 23 mm and the length of short stub Ls = 21.5 mm. The directive gains of 6.61 dBi is achieved.



a) E_ϕ at z-x Plane



b) E_θ at z-x Plane



c) E_θ at z-y Plane

Fig. 5: Electric field radiation pattern characteristic

4. Conclusion

The proposed IFA for UHF channel has been presented. The total length of the vertical and horizontal element of the proposed antenna is longer than a quarter wavelength. By increasing the height of the antenna and extending the conducting plane size the bandwidth enhancement achieved. Impedance matching can be obtained by adjusting horizontal elements without adding a matching circuit. The short stub adjustment does not affect the gain significantly. In the case of the height of antenna 38.3 mm, while the length of the short stub 30.7 mm and the size of conducting plane is 115 mm by 230 mm, the return loss bandwidth (-10 dB) becomes 2.4 % and the gain becomes 6.58 dB, respectively. When the height of the antenna become two times, the return loss bandwidth becomes almost three times. The proposed IFA is promising as antenna receiver for UHF channel application.

Acknowledgement

The authors would like to express special thanks of gratitude to the State Polytechnic of Malang for supporting this research.

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