Ultra Low Profile, Unbalanced Fed Inverted F Antenna for 2.45 GHz Wireless Communication System

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Abstract—**An ultra low profile unbalanced inverted antenna is proposed, which is analyzed numerically and its characteristics are compared with those ultra low profile inverted L antenna and conventional base fed inverted antenna then compared with its measured results. The design frequency is 2.45 GHz. When the size of conducting plane is 0.245 λ by 0.49 λ and antenna height is λ/20, the return loss bandwidth less than -10 dB becomes 3.67 % and the directive gain is 4.15 dBi. In the numerical analysis, the electromagnetic simulator "WIPL-D" based on the method of moment is used.**

I. Introduction

The small and low-profile antenna for the miniaturization of communication equipment is needed for mobile communication systems. The low profile antennas do not extend very far from the surface they are mounted on.The well known low profile antenna is inverted F antenna for its abilities to allow a simplify impedance matching and to controlling both the return loss bandwidth and directive gain [1]. The inverted F antenna possesses good properties as required for wireless local area network application and mobile applications and it also provide a fairly return loss bandwidth. For further information refer to [2], [3], [4], [5] and [6]. In this paper, the ultra low profile, unbalanced fed inverted F antenna is proposed and its characteristics are compared with the previous proposed low profile unbalanced inverted L antenna which is located very close on a rectangular conducting plane [7] and [8]. Measured trough the fabrication is needed to validate its calculation characteristics. The proposed ultra low profile, unbalanced inverted F antenna, and then we called ULPIF for the convenience. In the numerical analysis, the electromagnetic simulator "WIPL-D" is used [9].

II. Analytical Model

The unbalanced fed inverted F antenna is identical to a transmission line antenna of length $h + L + Ls \approx \lambda/4$. Alternately, the configuration is treated as a small loop inductor, consisting of the feed probe and the inverted L element behind the feed point, resonated with the capacitance of a horizontal wire above a ground plane, shown by Fig. 1. The sum of horizontal elements, *L, Ls* and the height antenna effects to the resonant frequency of the antenna. If the antenna height h is low, a capacitive coupling between conducting plane and the upper part of antenna occurs; hence the total length of horizontal element can be reduced. The length of short stub *Ls* has no effect onto the resonant frequency but to the input Impedance [10].

Fig. 1 shows the structure of the proposed ULPIF antenna located on a rectangular conducting plane (*pxp+pxm* by *pyp+pym*) and its size is fixed as *pxp=pxm*=15mm, *pyp*=43.2mm and *pym*=16.8mm when the length of short stub *Ls* is 6.8mm. The coaxial radiator is mounted on the conducting plane. The radius of the outer conductor is 0.8 mm and that of the inner conductor is 0.16 mm. The inner conductor of the coaxial cable is extended from the end of outer conductor. Therefore, this antenna is excited at the end of outer conductor. The height of horizontal element is *h*. The design frequency is 2.45 GHz. The wavelength λ at 2.45 GHz is 122.45 mm.

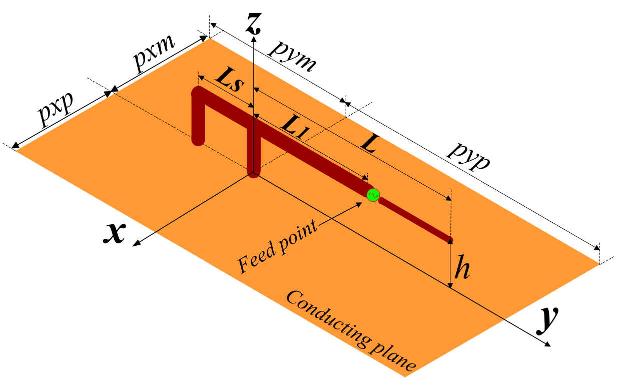

Fig. 1. Structure of the proposed ULPIF

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III. Results and Discussion

The ULPIF antenna is analyzed by adjusting the antenna height *h*. The limitation maximum h is 1/10 λ (wavelength). The heights *h* are 6mm, 8mm and 10 mm for the calculation analysis. The length of short stub *Ls* is adjusted in order to enhance the antenna gain even though it has limitation when the horizontal antenna very closed to the conducting plane. The length of horizontal antenna *L1* is adjusted in order to tune at the frequency design, on the other hand other horizontal *L* is adjusted due to impedance matching 50 Ohm. The length of horizontal elements *L* and *L1* are increased by reducing the antenna height.

Table 1 shows the calculated return loss bandwidth and the directive gains in the z direction of ULPIL antenna, ULPIF antenna and low profile conventional base fed inverted F (Base Fed IF) antenna for different antenna height *h*. The directive gain of ULPIF antenna is larger than that of ULPIL antenna. This may be due to that the total length of horizontal element of the ULPIF antenna *L*+*L1* + *Ls* is a little bit longer than that of ULPIL antenna. When the height h is 0.08λ, the total length element of ULPIF and ULPIL are 0.34 λ and 0.3λ, respectively. The base fed IF antenna has wider the bandwidth antenna and smaller gain than the ULPIF. Increasing the antenna height decreases the total of horizontal element. The calculation results indicate the antenna return loss bandwidth increases nearly linearly with the antenna height; on the other hand the directivity reduces.

TABLE I
Return Loss Bandwidth and Directive Gain of ULPIL and ULPIF Antenna for Different height of Antenna at 2.45 GHz

h	*L*	*L1*	Return Loss Bandwidth			Directive Gain at 2.45 GHz [dBi]
[mm]			f-low [GHz]	f-high [GHz]	%	
ULPIL						
6	29.7	18.3	2.40	2.50	4.08	4.03
8	28.4	14.2	2.38	2.53	6.12	3.88
10	26.8	10.0	2.35	2.55	8.16	3.68
ULPIF, *Ls*=6.8 mm						
6	30.0	19.2	2.41	2.50	3.67	4.15
8	29.1	15.2	2.38	2.52	5.71	4.03
10	27.8	11.1	2.46	2.55	7.76	3.85
Base Fed IF, *Ls*=6.8 mm						
6	29.0	17.2	2.15	2.64	20.00	3.67
8	28.1	15.8	2.22	2.61	15.92	3.76
10	27.0	14.6	2.27	2.61	13.88	3.76

Table 2 shows the calculated return loss bandwidth of ULPIF antenna and the directive gain in the z direction for different length of short stub *Ls* and antenna height *h* when the size conducting plane *pxp*=*pxp*=15mm by *pym*=16.8mm + *pyp*=42.2 mm at 2.45 GHz The length of short stub *Ls* can be reduced due to the antenna gain enhancement, on the other hand the bandwidth antenna little bit becomes narrower. The Ls adjustment almost doesn't affect on the length of horizontal elements *L* and *L1*.

TABLE 2
Return Loss Bandwidth and Directive Gain of ULPIF Antenna for Different height and Length Short Stub of Antenna at 2.45 GHz

Ls	*L*	*L1*	Return Loss Bandwidth			Directive Gain at 2.45 GHz [dBi]
[mm]			f-low [GHz]	f-high [GHz]	%	
h=6mm						
4	30.4	18.8	2.40	2.50	4.08	4.18
5.6	30.1	19.0	2.40	2.50	4.08	4.17
6.8	30.0	19.2	2.41	2.50	3.67	4.15
8	29.9	19.2	2.41	2.50	3.67	4.13
h=8mm						
4	29.1	15.0	2.38	2.53	6.12	4.05
5.6	29.1	15.0	2.38	2.53	6.12	4.04
6.8	29.1	15.2	2.38	2.52	5.71	4.03
8	29	15.5	2.38	2.52	5.71	4.00
h=10mm						
4	27.8	10.9	2.35	2.56	8.57	3.88
5.6	27.8	11.0	2.36	2.56	8.16	3.87
6.8	27.8	11.1	2.36	2.55	7.76	3.85
8	27.7	11.3	2.36	2.55	7.76	3.82

Figure 2a and Figure 2b show the calculated input impedance and return loss characteristics result between ULPIF (*h*=10mm, *Ls*=6.8mm, *pxp*=*pxm*=15mm, *pym*=16.8mm, *pyp*=43.2mm), ULPIL (*h*=10mm, *pxp*=*pxm*=15mm, *pym*=10mm, *pyp*=50mm) and Base Fed IF antenna (*h*=10mm, *Ls*=6.8mm, *L1*+*Ls*=21.4mm, *L*+*Ls*=33.8mm, *pxp*=*pxm*=10.4mm, *pym*=16.8mm, *pyp*=43.2mm).

Figure 2c and Figure 2d show comparison return loss bandwidth and the directive gain between ULPIL (*pxp*=*pxm*=15mm, *pym*=10mm, *pyp*=50mm), ULPIF (*Ls*=6.8mm, *pxp*=*pxm*=15mm, *pym*=16.8mm, *pyp*=43.2mm) with different *h* at 2.45 GHz and Base Fed IF antenna (*h*=10mm, *Ls*=6.8mm, *L1*+*Ls*=21.4mm, *L*+*Ls*=33.8mm, *pxp*=*pxm*=10.4mm, *pym*=16.8mm, *pyp*=43.2mm). The antenna bandwidth increases linearly, by increase the antenna height.

Figure 3 shows the directive gain of ULPIF antenna (*h*=10mm, *pxp*=*pxm*=15mm, *pym*=16.8mm, *pyp*=43.2mm) by investigate on length of short stub *Ls*.

Figure 4a shows the photograph of fabricated ULPIF antenna. Figure 4b and Figure 4c show the return loss and the input impedance characteristics of the ULPIF antenna, respectively. In the calculation the parameters are *h*=10mm, *Ls*=6.8mm, *L1*+*Ls*=17.9mm, *L*+*Ls*=34.6mm, *pxp*=*pxm*=15mm, *pym*=16.8mm, *pyp*=43.2mm and in the measurement are *h*=10mm, *Ls*=6.6mm, *L1*+*Ls*=17.1mm, *L*+*Ls*=34.1mm, *pxp*=*pxm*=15mm, *pym*=16.8mm, *pyp*=43.2mm. The measured results are agree well with the calculated results.

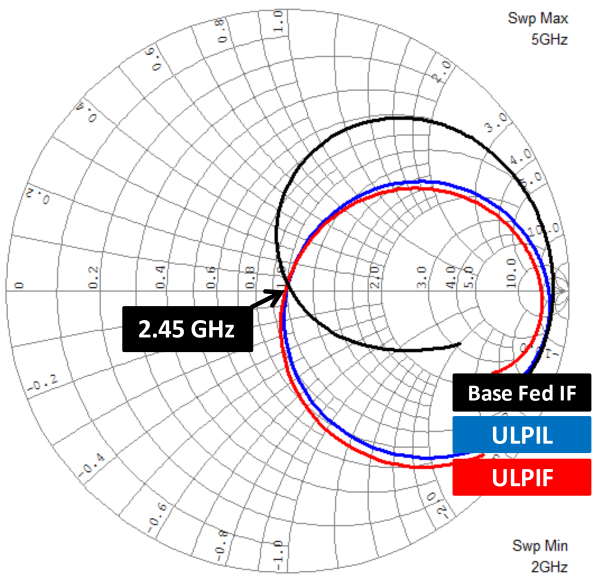

Fig. 2a. Input Impedance characteristic of ULPIL (*h*=10mm, *pxp*=*pxm*=15mm, *pym*=10mm, *pyp*=50mm), ULPIF (*h*=10mm, *Ls*=6.8mm, *pxp*=*pxm*=15mm, *pym*=16.8mm, *pyp*=43.2mm) and Base Fed IF antenna (*h*=10mm, *Ls*=6.8mm, *L1*+*Ls*=21.4mm, *L*+*Ls*=33.8mm, *pxp*=*pxm*=10.4mm, *pym*=16.8mm, *pyp*=43.2mm).

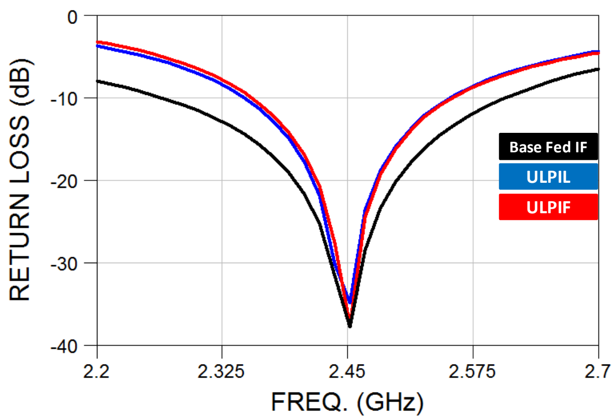

Fig. 2b. Return Loss characteristic of ULPIL (*h*=10mm, *pxp*=*pxm*=15mm, *pym*=10mm, *pyp*=50mm) ULPIF (*h*=10mm, *Ls*=6.8mm, *pxp*=*pxm*=15mm, *pym*=16.8mm, *pyp*=43.2mm) and Base Fed IF antenna (*h*=10mm, *Ls*=6.8mm, *L1*+*Ls*=21.4mm, *L*+*Ls*=33.8mm, *pxp*=*pxm*=10.4mm, *pym*=16.8mm, *pyp*=43.2mm).

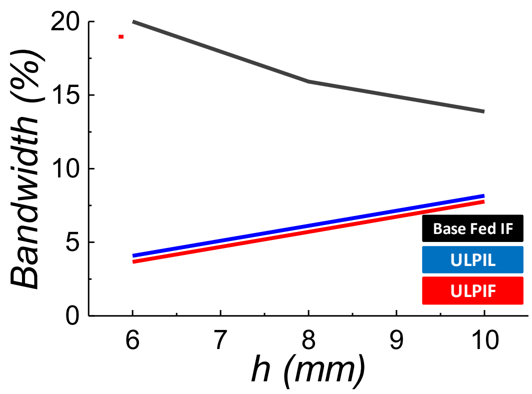

Fig. 2c. Comparison the return loss bandwidth between ULPIL, ULPIF and Base Fed IF antenna with different *h* at 2.45 GHz.

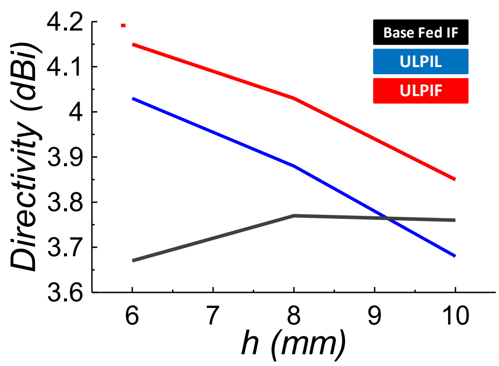

Fig. 2d. Comparison the directive gain between ULPIL, ULPIF and Base Fed IF antenna with different *h* at 2.45 GHz.

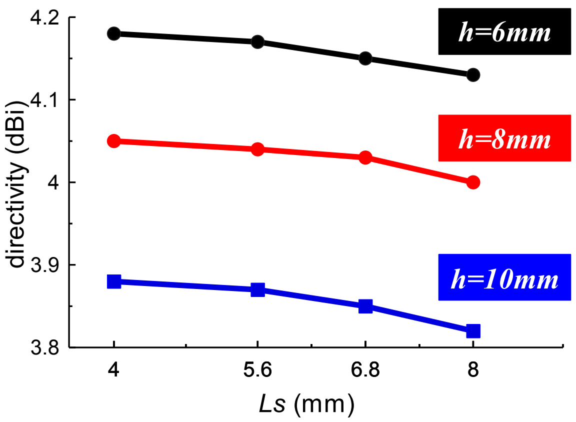

Fig.3. The directive gain of ULPIF at 4.25GHz (*pxp*=*pxm*=15mm, *pym*=16.8mm, *pyp*=43.2mm) with different *Ls*.

IV. Conclusion

The ULPIF antenna on a rectangular conducting plane has been proposed. The return loss and the directive gain of this antenna has been compared with those of the base fed inverted F antenna and the ULPIL antenna. The directive gain of proposed antenna is higher than that of base fed inverted F antenna. When the size of conducting plane is 0.245 λ by 0.49 λ and antenna height is λ/20, the return loss bandwidth less than -10 dB becomes 3.67 % and the directive gain is 4.15 dBi. The measurement results are agree well with the calculation results. This ULPIF antenna may be promising as the base station antenna or mobile terminal antenna of the wireless communication system.

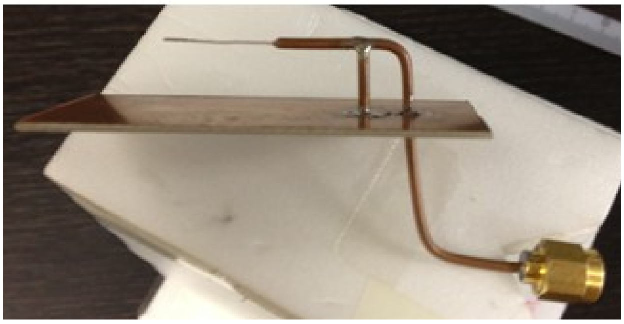

Fig. 4a. The photograph of fabricated ULPIF antenna (*h*=10mm, *Ls*=6.6mm, *L1*+*Ls*=17.1mm, *L*+*Ls*=34.1mm, *pxp*=*pxm*=15mm, *pym*=16.8mm, *pyp*=43.2mm).

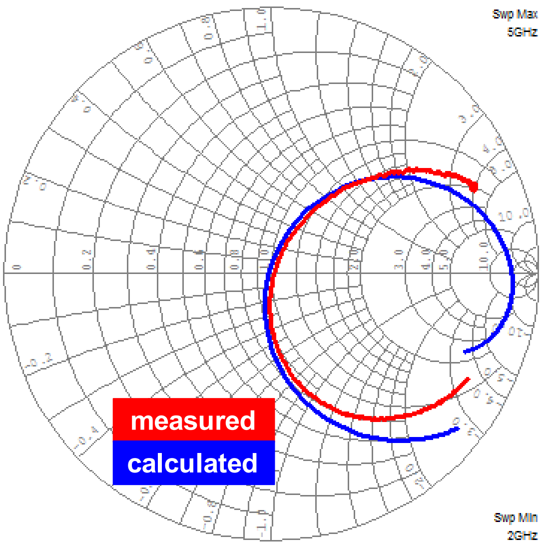

Fig. 4b. Input Impedance characteristic of ULPIF (Calculation; *h*=10mm, *Ls*=6.8mm, *L1*+*Ls*=17.9mm, *L*+*Ls*=34.6mm, *pxp*=*pxm*=15mm, *pym*=16.8mm, *pyp*=43.2mm) and (Measurement; *h*=10mm, *Ls*=6.6mm, *L1*+*Ls*=17.1mm, *L*+*Ls*=34.1mm, *pxp*=*pxm*=15mm, *pym*=16.8mm, *pyp*=43.2mm).

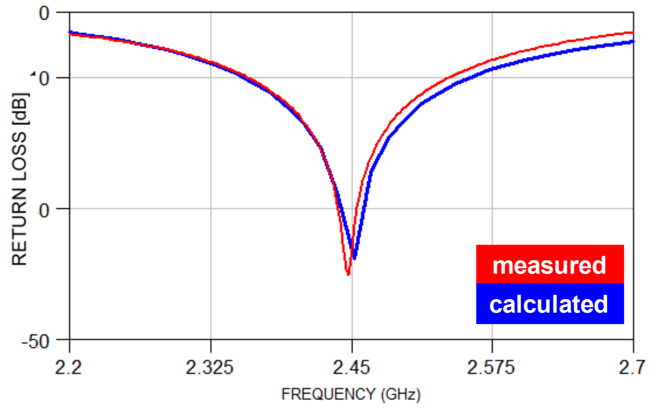

Fig. 4c. Return Loss characteristic of ULPIF (Calculation; *h*=10mm, *Ls*=6.8mm, *L1*+*Ls*=17.9mm, *L*+*Ls*=34.6mm, *pxp*=*pxm*=15mm, *pym*=16.8mm, *pyp*=43.2mm) and (Measurement; *h*=10mm, *Ls*=6.6mm, *L1*+*Ls*=17.1mm, *L*+*Ls*=34.1mm, *pxp*=*pxm*=15mm, *pym*=16.8mm, *pyp*=43.2mm).

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