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Modified Planar Inverted-L Antenna

Jonathan Evans
Dublin Institute of Technology

Max Ammann
Dublin Institute of Technology, max.ammann@dit.ie

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J.A. Evans and M. J. Ammann

School of Electronic and Communications Engineering, Dublin Institute of Technology,
Ireland.

email: jonathan.evans@comreg.ie

Abstract: A Hybrid Inverted-L Antenna (HIL) has been shown to reduce the physical height of
a square planar monopole antenna, while retaining a relatively wide impedance bandwidth and
good radiation pattern characteristics. The introduction of horizontal slots in the vertical edges
of the antenna cause the surface current to meander, resulting in a decrease in the lower edge
frequency of the impedance bandwidth. The impact of different sizes and arrangements of slots
on impedance and radiation pattern bandwidth, gain and surface current distribution is simulated
using Transmission Line Modelling (TLM). Simulated results for impedance bandwidth are
verified with measurements. With other modifications these antennas are proposed for wireless
and mobile applications in the 2.45 GHz and 5.8 GHz ISM bands.

1. INTRODUCTION

Desirable antenna characteristics for modern mobile applications include wide
impedance bandwidth, omni-directional radiation pattern, low profile and inexpensive
manufacture. The planar monopole antenna is a simple low cost structure that has been
shown to yield a wide impedance bandwidth and an omni-directional radiation pattern
[1]. A reduction in the high profile of the planar monopole antenna by removing
material and folding over sections to form a Hybrid Inverted-L (HIL) antenna have
previously been investigated [2], Fig. 1(a). Such antennas have been considered
suitable for application in a wide range of mobile applications including systems
operating in the 2.4 and 5.8GHz ISM bands.

2. HIL ANTENNA

The HIL antenna is constructed from 0.2mm brass sheeting and is mounted on a 100mm
square ground plane with a 2mm feedgap. The dimensions of the planar element as
shown in Fig. 1(a) are: H=20mm, W=40mm, Pl=20mm, and Pw=10mm. The planar
element is fed via a probe feed from a coaxial cable via an SMA type connector.
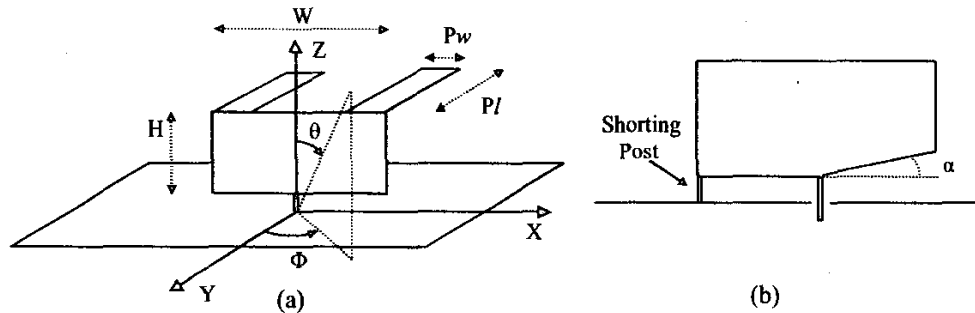

Figure 1: (a) HIL antenna shown with co-ordination system. (b) vertical section of HIL
antenna with a taper (angle α) and a shorting post (see Section 3.2).

3. MODIFIED HIL ANTENNAS

3.1 Slotted Antennas

Based on TLM simulations, surface current density is found to be most significant along the lower horizontal and vertical edges of the vertical planar element. The introduction of slots into the vertical edges of the vertical planar element (Fig. 2(a)) can cause the current to meander (Fig. 2(b)) with the effect of producing a lower limit on the antenna's frequency response – effectively yielding a given frequency response from a smaller antenna. Various different slotted arrangements and sizes were simulated on the HIL antenna and are tabulated in Table 1 below.
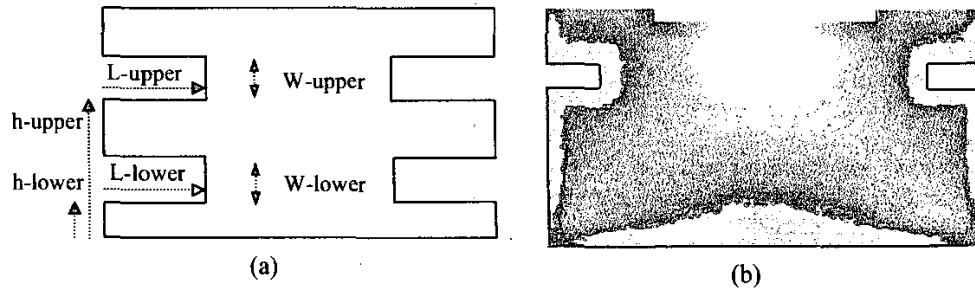

(a)   (b)

Figure 2: (a) vertical section of slotted HIL antenna – in some cases there is only a single slot per side. (b) TLM simulation of surface current density on the vertical section of a slotted HIL antenna – the darker areas represent stronger current density.

Antenna	Lower (mm)			Upper (mm)			10 dB RL (MHz)		6 dB RL (MHz)	
	h	L	W	h	L	W	Lower	Upper	Lower	Upper
HILa	-	-	-	-	-	-	2190	3220	1930	3600
HILb	10	5	1	-	-	-	2180	3176	1920	3550
HILc	9	5	2	-	-	-	2200	3170	1920	3530
HILd	7.5	5	5	-	-	-	2200	3060	1880	3480
HILe	5	5	10	-	-	-	2200	2950	1840	3380
HILf	4.5	5	2	-	-	-	2200	3195	1900	3580
HILg	14	5	2	-	-	-	2180	3100	1900	3470
HILh	4	5	2	14	5	2	2180	3080	1870	3480
HILi	4	5	2	14	10	2	2370	2370	1850	3080

Table 1: Slotted HIL antennas and their simulated return losses (RL).

3.2 Taper and Shorting Post

The inclusion of a shorting post between the lower horizontal edge of the planar element and the ground plane can help reduce the lower portion of the antenna's frequency response [4]. Furthermore, modifying a planar monopole antenna with a tapered lower horizontal edge has been shown to increase the upper edge frequency [5]. Applying these techniques to the HIL antenna cause the useful operational range of the antenna to extend to the 5GHz region making it suitable for applications in the 5.8GHz ISM band. The optimum response here is achieved with a 1mm feed gap and a 15° taper is applied on one side of the lower edge (Fig. 1(b)) with a shorting post on the opposite side.
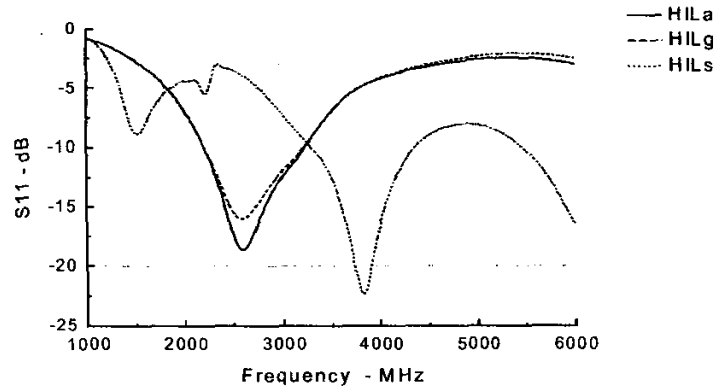
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Figure 3: Simulated swept Return Loss comparison for HILa, HILg, and HILts (HIL with taper and shorting post – Fig.1(b)).

The effect of the horizontal slots is more pronounced on measured results taken from the antennas yielding a reduction in 10dB lower edge frequency of up to 117MHz (~5% of unmodified HIL lower edge frequency – 2217MHz):

Antenna	Simulated 10 dB RL (MHz)		Measured 10 dB RL (MHz)	
	Lower	Upper	Lower	Upper
HILa	2190	3220	2217	3558
HILb	2180	3176	2118	3407
HILg	2180	3100	2100	3540
HILh	2180	3080	2180	3280
HILts	3140/ 5163	4122/ 7676	3430/ 5400	3930/ 6000+

Table 2: Simulated and measured 10dB RL cross-over frequencies. Note – HILts has two regions that dip below 10dB.

The measured swept return loss compares reasonably well to the simulated results for the slotted HIL antennas listed above (HILa,b,g,h). The simulated lower –10dB edge frequency is typically within 4% of the measured value (< 80MHz) for the slotted HIL antennas whereas the simulated upper –10dB edge frequency is less accurate and is typically within ± 12% (440 MHz) of the measured value. There is a discrepancy of approximately 10% between the simulated and measured results for the shorted/tapered HIL antenna (HILts).

4. RADIATION PATTERN AND GAIN CHARACTERISTICS

4.1 Radiation Pattern

The insertion of the various different types of slots has no evident effect on the radiation patterns of the antennas simulated. The E-plane $-E_\theta(\theta, \phi = 0)$ – radiation pattern yields good performance in the upper hemisphere with variations of less than 15dB within the antenna's impedance bandwidth (Fig. 4(a)). The H-plane $-E_\theta(\phi, \theta = 90)$ – radiation pattern is omni-directional and remains constant within ± 3dB over the frequency range of the slotted HIL antennas (Fig. 4(b)).
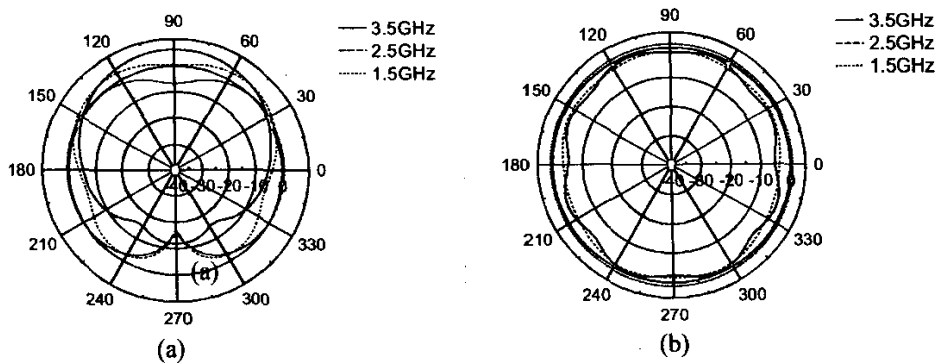
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Figure 4: (a) E-Plane patterns $E_\theta\,(\theta,\phi = 0)$ and (b) H-Plane patterns $E_\theta\,(\phi,\theta = 90)$

4.2 Gain Characteristics

Although the gain characteristics of the various modified HIL antennas increases with frequency – as the antenna becomes less omni-directional – they remain consistent for the various modifications implemented. Simulated gains for the slotted HIL antennas are between 1.522 and 1.564dBi at 1.5GHz, 6.338 and 6.388dBi at 2.5GHz, and 6.819 and 6.953dBi at 3.5GHz. The gains of the HILts antenna are 1.7, 6.023, and 7.577dBi at 1.5, 2.5, and 3.5GHz respectively.

5. CONCLUSION

The introduction of horizontal slots to a Hybrid Inverted-L (HIL) antenna has been shown, using TLM simulations, to cause surface current to meander. This has been measured to yield a decrease in the lower edge 10dB return loss frequency of up to 5%, thus making the design more compact. The introductions of a tapered lower edge and a shorting post to a HIL antenna are shown to broaden and shift the frequency response of the antenna upwards to operate at frequencies from 3.4 to over 6GHz. This antenna could be used for applications in the 5.8GHz ISM band whereas the slotted HIL antennas could also be used in the 2.4GHz band. The slotted modifications are shown to have no effect on the radiation patterns, which remain relatively consistent over the impedance bandwidth ranges. The gain of the antennas are also relatively unaffected by the slotted modifications.

6. REFERENCES

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