User Terminal Antennas for DVB-H Systems: An Overview

Leandro de Haro, Carlos Redondo, Manuel de la Puebla, Jose Manuel Arias.

Abstract—**Antenna is one of the key systems to define the feasibility of the deployment of convergent wireless system between DVB-H and e.g. UMTS. INSTINCT project within WP4 (Terminal front-end aspects) is covering this issue. This paper presents the conclusions about antenna design up to now, and some results and prototypes obtained. As conclusions, passive antennas are just useful for category 1 and 2a terminals, whereas tuned antennas can be applied for category 2b and 3 terminals. Although active antennas are not the target of this study, they should be used in case it is necessary to reduce more the antenna size.**

***Index Terms*— UHF Antennas, Small Antennas**

I. Introduction

THE availability of nomadic terminals (unplugged or mobile) is a necessity in the actual convergence process between the digital TV and cellular systems (e.g. UMTS). In this framework DVB-T has evolved to the DVB-H to allow the TV and data reception in mobile terminals. Three terminal categories were defined in INSTINCT [1] following EICTA standard [2]:

- Category 1: terminals integrated in cars;
- Category 2: unplugged TV terminals; subdivided in 2a, receivers with a display larger than 25 cm, as the laptop PCs; and 2b, pocket TV terminals;
- Category 3: portable handheld terminals, which were simultaneously cellular phones.

This paper presents an overview of different designs applicable to each terminal category. Moreover, each antenna has been simulated using the CST Microwave Studio® [3] and two of them has been prototyped up to now.

Several solutions have been presented, which may be classified within each category: log-periodic and spiral antennas for the category 1; circular monopoles and bowties for category 2a. Although several passive antennas based on IFA and PIFA concepts has tried for categories 2b and 3, the size requirement is incompatible with UHF bandwidth covering, so tuned antennas have found as the only proposal for category 2b and 3. Active antennas have not been considered due to the constraints in the power consumption imposed to the user terminal.

This work was supported in part by European Commission (Framework Program 6) within INSTINCT project (Project Number 507014).

Leandro de Haro is in the Dept. Señales, Sistemas y Radiocomunicaciones, Universidad Politécnica de Madrid (E.T.S. de Ing. de Telecomunicación. Ciudad Universitaria. E-28040 Madrid (SPAIN) corresponding author to provide phone: +34915495700 ext 386, fax: +34915432002, e-mail:ldeharoariet@ ieee.org).

Carlos Redondo is now a PhD student whereas Manuel de la Puebla and Jose Manuel Arias developed their Master Thesis in the same Department in the UPM.

II. Category 1 Antennas

The standard antenna in a car is a $\lambda/4$ monopole mounted on the car roof acting as a metallic ground plane. However, the planar structures (spiral antennas or log-periodic antennas) can also be used. Antenna pattern is strongly dependent on the antenna position on the vehicle, so the gain will depend on it. Specified minimum gain is shown in table I. Polarization discrimination must be better than 4 dB, and it is also dependent on the position on the car roof. This value justifies the usage of a diversity system.

TABLE I
SPECIFIED GAIN FOR CATEGORY 1 ANTENNAS

UHF Channel	Central frequency	Gain
21	474 MHz	-3 dBi
49	698 MHz	0 dBi
69	858 MHz	1 dBi

A. Log Periodic Antennas

A log-periodic antenna has been simulated based on the design of DuHamel [4]. Antenna has a size about 50 cm, and a bandwidth with return losses lower than -10 dB that goes from 470 MHz up to 2 GHz. The gain is of 5 dB at 858 MHz with a pattern very stable. The antenna may be integrated within the car rear window following the transformation in a wire structure proposed in [5].

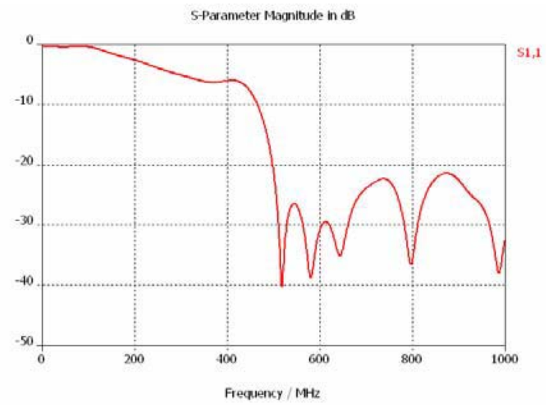

Fig. 1. Insertion losses for the log-periodic antenna.

B. Spiral Antennas.

An Archimedes spiral antenna, working in axial mode, has been designed. Following [6], the minimum diameter is λ/π at the minimum frequency (470 MHz), that is to say, 2.3 cm. The bandwidth for insertion losses is better than -10 dB between 467 MHz to 996 MHz, and it is achieved just with three turns and a maximum diameter of 24 cm. The gains obtained are 3.85 dBi (at 474 MHz), 3.97 dBi (at 698 MHz) and 4.34 dBi (at 858 MHz). The radiated polarization is mainly circular, and nearly perfect at the orthogonal direction to the spiral plane.

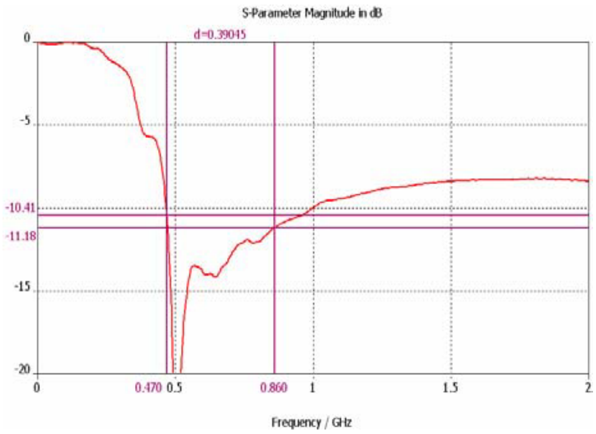

Fig. 2. Insertion losses for the spiral antenna.

III. CATEGORY 2A ANTENNAS

The reference antenna is a $\lambda/2$ dipole so cuasi-omnidirectional patterns are expected and the maximum size should be smaller than 15 cm. The gain is limited by the low efficiency of the small radiant structures and its minimum values can be found in table II. At bands IV and V of UHF it is possible a polarization discrimination up to 4 dB. The solutions proposed for this category are the planar circular monopole, and the bowtie antenna.

TABLE II
SPECIFIED GAIN FOR CATEGORY 2A ANTENNAS

UHF Channel	Central frequency	Gain
21	474 MHz	-6 dBi
49	698 MHz	-1 dBi
69	858 MHz	0 dBi

A. Circular Monopoles

Circular, elliptical, rectangular and hexagonal planar monopoles have been studied in [7]. Finally, the circular one was selected by its large bandwidth. Figure 3a shows a sketch of the designed monopole mounted on a laptop PC. A mechanism to flip up and down may be installed to deploy the antenna when necessary. The circular dipole has a diameter of 10 cm and it must be mounted on a coplanar ground plane which it is available because of the PCB metallization on the back of the display. The prototype, as it shows figure 3b, includes a ground plane, with a height of 27.5 cm and a length of 38 cm that are the dimensions of a laptop PC.

The insertion losses, referred to 50 Ω (SMA connector), depend on the gap height between ground plane and antenna [8], and it has been optimized. Measurements in fig. 4 show an insertion loss better than -10 dB all over the bandwidth between 470 and 860 MHz. Figure 5 shows the measured co-polar component of the radiation pattern at 676 MHz on the horizontal plane (ZX of figure 3a). It is cuasi-omnidirectional. The co-polar/cross-polar ratio (axial ratio) at 676 MHz in the worst plane (Φ = 45º) is better than 4 dB. Finally, the estimated gain (by simulation) is higher than 2 dBi all over the bandwidth.

Fig. 3a/b. Antenna installation concept and prototyping including the metallization of the portable PC back and the antenna.

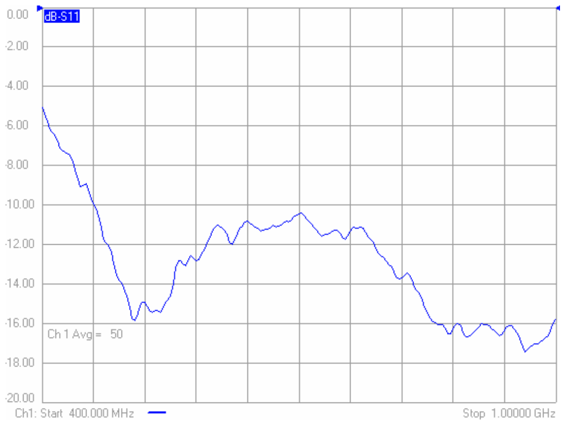

Fig. 4. Measured insertion losses for the circular dipole antenna.

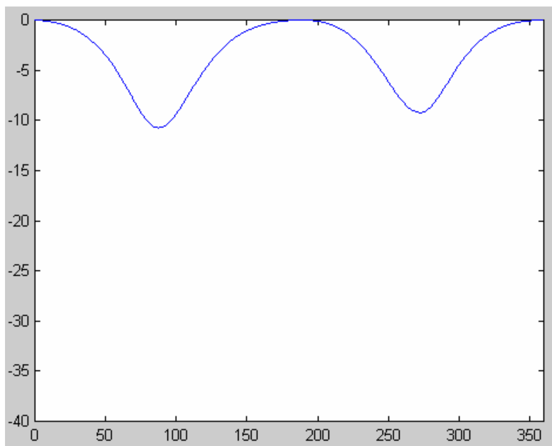

Fig. 5. Measured co-polar pattern at the horizontal (ZX) plane at 676 MHz for the circular dipole antenna.

B. Bow Tie Antenna

Bowtie antenna consists on a circular sector over a ground metallic plane (figure 3a). The ground plane simulates the effect of PCB on the back of the display of a laptop PC (prototyped, as it can be seen in figure 3b, with a height of 27.5 cm and a length of 38 cm). The height of the bowtie is 8.2 cm, obtained to optimize the gain. Moreover, the sector angle and the gap height between the laptop display and the antenna define the insertion losses (measurement in figure 7), in this case, better than -8 dB. Figure 8 shows the measured co-polar pattern for the horizontal (ZX) plane. The co-polar/cross-polar ratio at 676 MHz for the worst plane, Φ = 45º is better than 4 dB. The antenna gain, computed by means of simulations, has the following values: 2.7 dBi (474 MHz), 2.6 dBi (698 MHz) and 3.1 dBi (858 MHz).

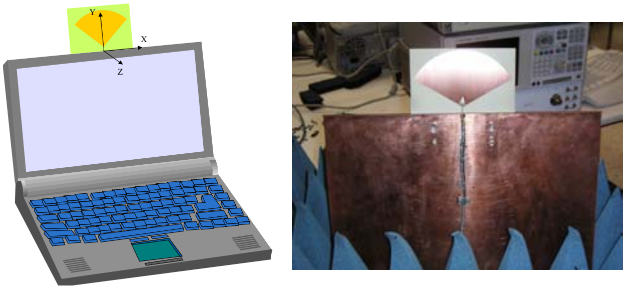

Fig. 6a/b. Antenna installation concept and prototyping including the metallization of the portable PC back and the antenna.

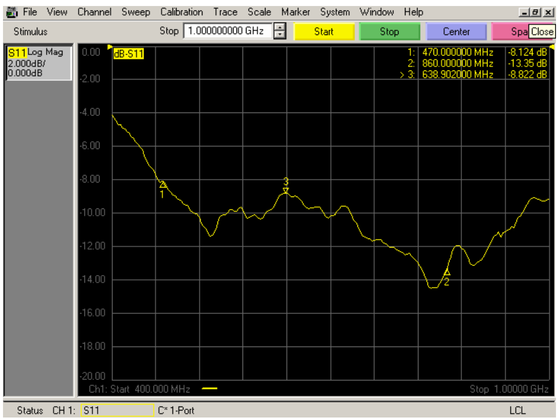

Fig. 7. Measured insertion losses for the bowtie antenna.

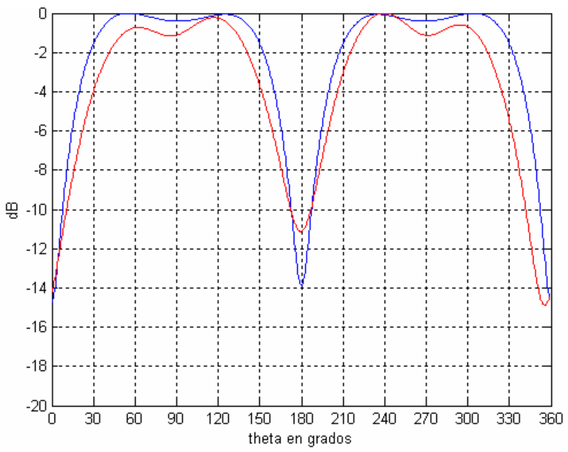

Fig. 8. Measured (in red) and simulated (in blue) co-polar pattern at the horizontal (ZX) plane at 676 MHz for the bowtie antenna.

IV. CATEGORY 2B AND 3 ANTENNAS

Under this category, one considers those small antennas integrated in a terminal. The design should be done including the terminal. The minimum specified gains can be seen in Table III. Whereas category 2b covers those (larger) terminals which may be used in the full UHF band, category 3 is applied just for the convergent terminals with the bandwidth limited to channel 49 (698 MHz) to allow the operation in presence of GSM900. However, the size requirement is the most important one, because the antenna should be installed on a handheld terminal (typically 7.5x9x2 cm)

TABLE III
SPECIFIED GAIN FOR CATEGORY 2B&3 ANTENNAS

UHF Channel	Central frequency	Gain
21	474 MHz	-10 dBi
49	698 MHz	-7 dBi
69	858 MHz	-5 dBi

A. *Passive IFA Antenna*

A very large bandwidth IFA has been designed, inspired in Nakano concept [9] but with four parasitic elements and a matching improvement using a LC network. The design was centred in the central band of UHF, but some conclusions can be obtained. The bandwidth for a SWR of 2 has been enough improved (from a 27.1% to a 36.9% as it can be seen in figure 9) to cover a category 3 terminal, but the volume (8x6x4 cm) is too big to be used in a terminal. Moreover, there are no bandwidth extensions for terminal 2b.

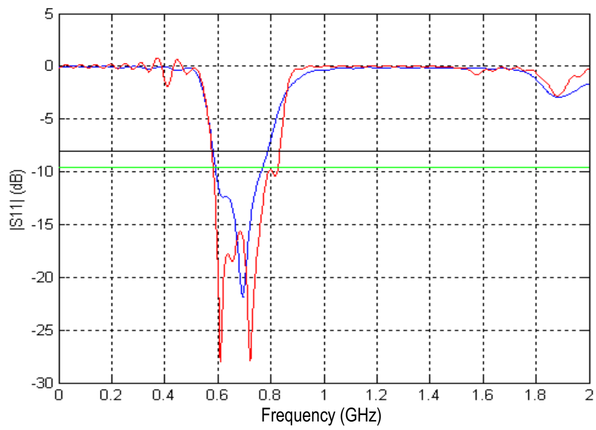

Fig. 9. Comparison of simulated insertion losses for the IFA antenna between Nakano concept (blue) and our concept (red).

B. *Passive PIFA Antenna*

Several PIFA antennas have been tried but bandwidth is not enough to cover all UHF band. Ideas from Liu on [10] or those geometries described by Chiu and Huynh in [11] and [12], respectively, and Wong [13] ideas to enlarge bandwidth using resistors, all of them, have been tried without success. Just the concept from Lee [14] provides large bandwidth, but with bad insertion losses that are only better than -6.5 dB. Figure 10 shows the plot. Moreover, the necessary volume is too big (14.3x9.5x4.8 cm).

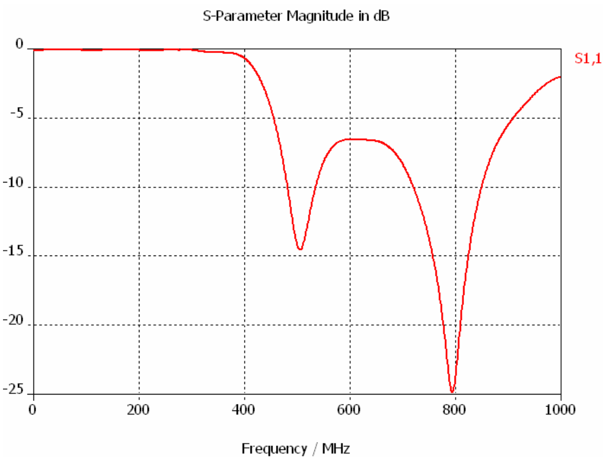

Fig. 10. Insertion loss for Lee's PIFA design covering UHF band ($|S_{11}|$<-6.5 dB).

C. *Tuned PIFA Antenna*

Passive antennas are size limited by Chu-Wheeler criteria. Applying it at 665 MHz, it provides a minimum radius of the sphere that closes the antenna of 8 cm when the SWR is -8dB.

It is necessary to include a non passive element to reduce Chu's minimum size. The easiest solution is to include a variable capacitor, as a varactor, as well as a RF-MEM. Typical varactors have variations of 1:6 whereas RF-MEMs vary even 1:15.

The solution proposal is a PIFA with a volume of 6x4x1 cm, which insertion losses has been optimised for covering just UHF band IV (for category 3 antennas). As it can be seen in figure 11, simulations demonstrate that a variation of 1pF to 4 pF covers from 470 MHz to 700 MHz with a $|S_{11}|$<-15 dB. Although the design has not been optimised in the upper band, extending the capacitor variation from 0.1pF to 1pF it may also cover band V with $|S_{11}|$<-10 dB. Gain is of 1 dBi at 470 MHz and of 2 dBi at 700 MHz.

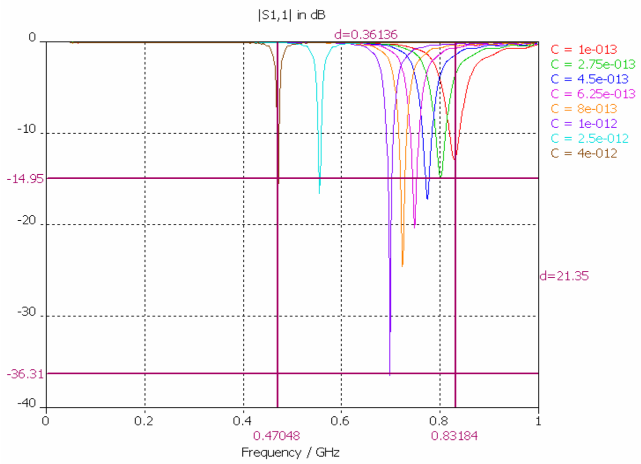

Fig. 11. Simulated insertion loss for tuned PIFA design in terms of capacitor value. UHF band IV is covered by varying C from 1pF to 4 pF. Extending the capacity variation it is possible to cover band V too.

In case of reducing the antenna size, the gain goes down sharply. For instance, using a meandered PIFA to enlarge current path as much as possible, it is possible to reduce the antenna volume to 4 x 2.5 x 0.4 cm. The gain is now -16 dBi, but the bandwidth covers all UHF band IV. Therefore, this design is a good candidate to be used as a starting point of a classical active antenna.

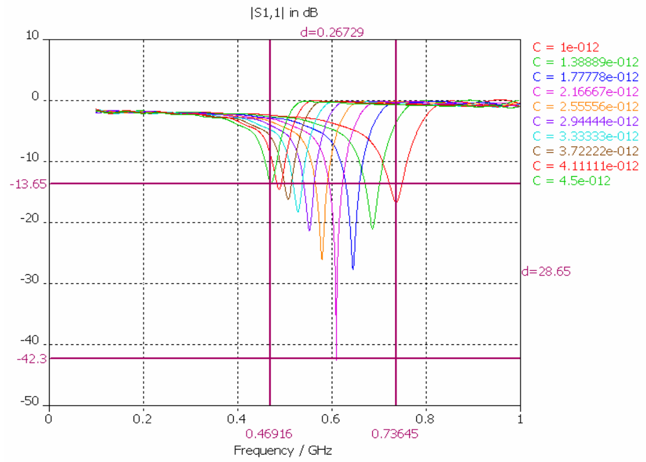

Fig. 12. Simulated insertion loss for tuned meandered PIFA design covering

V. Conclusion

Several antennas have been studied for different categories of user terminals. The best solutions for antennas integrated in cars are spirals or log-periodic antennas. On the other hand, a good solution for antennas on laptop PCs is the circular dipoles. Bowtie has a worst performance, simply, because it is smaller. However, in case of handheld terminals, passive antennas do not fulfil with size restrictions or providing good matching all over UHF band. Chu-Wheeler criterion predicts a minimum sphere radius of 8 cm for a right performance. A good solution is the tuned antennas as the PIFA designed shown in this paper.

Acknowledgment

The authors acknowledge the support for this work that is funded by the EU under the IST program as the project INSTINCT (IP-Based Networks, Services and TermINals for Converged SysTems), IST-507014. The authors also want to acknowledge all partners in INSTINCT, especially those in the Front-end Terminal Aspects work package (WP4).

References

[1] WP4 / D4.1 deliverable. "Front-end and Antennas External Specification". ISTINCT Project. May 2004.
[2] EICTA / TAC / MBRAI-02-16 [Version 1.0 (1.1.2004)]
[3] CST Microwave Studio® from Computer Simulation Technology. http://www.cst.de/Content/Products/MWS/Overview.aspx
[4] R. H. DuHamel and D. E. Isbell, "Broadband Logarithmically Periodic Antenna Structures", 1957 IRE National Convention Record, pt. 1, pp. 119-128.
[5] C. A. Balanis, "Antenna Theory: Analysis and Design", 2nd ed., John Wiley & Sons, 1997.

[6] J.P. Jones, P.E Taylor, C.W. Morrow, "Design techniques for a light weight high power spiral antenna"
[7] N. P. Agrawall, G. Kumar and K. P. Ray, "Wide-Band Planar Monopole Antennas": IEEE Transactions on Antennas and Propagation, vol. 46, no. 2, pp. 294-295, February de 1998.
[8] C. Peixeiro, C. A. Fernandes, A. Moreira, M Caspstick, B. Kemp, J. Brissos, F. Guerra and B. Teixeira, "Antena Feasibility Study": IST-2001-32125 FLOWS Deliverable Number D7.
[9] H.Nakano, R.Suzuki, J.Yamauchi, "Low profile inverted F antenna with parasitic elements", IEE 1998.
[10] Z. D. Liu, P. S. Hall and D. Wake, "Dual-Frequency Planar Inverted-F Antenna": IEEE Transactions on Antennas and Propagation, vol. 45, no. 10, pp. 1451-1458, October de 1997.
[11] C. W. Chiu and F. L. Lin, "Compact dual-band PIFA with multi-resonators": Electronics Letters, vol. 38, no.12, pp. 538-540, 6 de June de 2002.
[12] T. Huynh and K. F. Lee, "Single-layer single-patch wideband microstrip antenna": Electronics Letters vol. 31, no. 16, pp. 1310-1312, 3 de August de 1995.
[13] K. L. Wong and K. P. Yang, "Modified Planar Inverted-F Antenna": Electronics Letters, vol. 34, no.1, pp. 7-8, 8 de January 1998
[14] C. L. Lee, B. L. Ooi, M. S. Leong, P. S. Kooi, T. S. Yeo, "A Novel Coupled-Fed Small Antenna", Proceedings of APMC2001, Taipei, Taiwan, R. O. C., 2001, pp. 1044-1046.
[15] Chu, L.J.: 'Physical limitations in omnidirectional antennas', J Appl. Phys, 1948, 19, pp. 1163–1175.
[16] Wheeler, H.A.: 'Fundamental limitations of small antennas', Proc IRE, December 1947, pp. 1479–1488