Compact Dual-Linear Polarized Wideband Antenna for VHF/UHF band.

Olivier Clauzier, Franck Colombel, Mohamed Himdi, Patrick Potier, Cyrille Le Meins

Compact Dual-Linear Polarized Wideband Antenna for VHF/UHF band

Olivier Clauzier, Franck Colombel, Mohamed Himdi, Patrick Potier and Cyrille Le Meins

O. Clauzier, F. Colombel and M. Himdi are with IETR, UMR CNRS 6164; C. Le Meins is with Thales Communications; P. Potier is with "Direction générale de l'Armement", Bruz.

ABSTRACT : A new compact dual-linearly polarized ultrawideband (UWB) antenna for VHF/UHF applications is proposed on this letter. The antenna is miniaturized thanks to inductive loading and lumped resistances. In addition, to reduce back radiation and to optimize the impedance matching at low frequencies, a ferrite layer is placed close to the radiating element. This antenna provides broadband characteristics and unidirectional radiation patterns over the whole bandwidth with a length and a height respectively limited to $\lambda_{LF}/6$ and $\lambda_{LF}/13$, where λ_{LF} is the wavelength at the lowest frequency of the operating band. Simulations and measurements are found to be in good agreements.

1 Introduction

Both industrial and military applications have a great interest in compact broadband antennas with unidirectional coverage. For instance, in airborne applications, there is a great need for low-profile antenna to minimize the impact on the aerodynamic performances. This is particularly challenging for VHF/UHF applications where the wavelengths can be greater than two meters. As a result, the physical size of the antenna can be very small compared to the wavelengths at low frequencies. Therefore, there is a great need to design broadband antennas on VHF and UHF bands because most of the civil or military radio communication systems are located on these bands. To meet these requirements, frequency independent antennas, like spiral [1] or sinuous antennas [2], are often used. Nevertheless, to work efficiently from 150 MHz, a circular Archimedean spiral needs an antenna with a diameter close to 0.64 m. In order to miniaturize antennas, one of the best solutions is to lengthen the current path. The inductive loading was previously introduced on the Archimedean spiral antenna. It is shown that meandered the arms of an Archimedean spiral antenna provides a higher realized gain [3, 4, 5] and best axial ratio [6] at low frequencies compared to an untreated wire spiral antenna. In [7], a low-profile and broadband Archimedean spiral antenna using both dielectric and inductive loading has been presented. The results demonstrate a 10 dB improvement of the boresight realized gain at 200 MHz by coiling the arms of a 150 mm (6") spiral antenna. Moreover, ferrite tiles are often used on spiral antenna to slow down the wave velocity thanks to the permeability and permittivity of this material [8, 9, 10]. To receive and treat all types of signals, it is useful to design antennas with multiple polarizations over the whole bandwidth. To meet these claims, a compact dual-linearly polarized bow-tie antenna is proposed for continuous operation from 100 MHz to 2000 MHz band [11]. This antenna presents a tapered horn sections and zigzag arms to improve performance over the whole bandwidth with a diameter of about 380 mm and height of about 150 mm. Nevertheless, we noticed a good return loss (S_{11} < -10 dB) only after 800 MHz. In this letter, a new compact dual-linear polarized ultrawideband antenna is proposed using inductive loading and lumped resistances to improve the performances at low frequencies. Ferrite tiles are also used to reduce the back radiation and to optimize the impedance matching at low frequencies. As a result, this antenna provides broadband characteristics and unidirectional radiation patterns between 150 MHz and 800 MHz with a length and a height respectively limited to $\lambda_{LF}/6$ and $\lambda_{LF}/13$, where λ_{LF} is the wavelength at the lowest frequency of the operating band.

2 Modified Bow-tie Antenna Design

The proposed solution, illustrated in Fig. 1, is a dual-linear polarized bow-tie antenna linked by a coiled crown. The antenna, with a diameter limited to 330 mm ($\lambda_{LF}/6$ at lowest operating frequency), is printed on a substrate with a thickness of 0.8 mm and dielectric constant of 3 (Neltec NX9300IM0787RHUN). The flare angle α is fixed at 40° to provide an input impedance close to 200 Ω. Four circular coils, with a diameter of 20 mm and a winding pitch of 5 mm, link the dipoles. A 300 Ω lumped resistance is placed between two consecutive coils in order to improve the Voltage Standard Wave Ratio (VSWR) at low frequencies. The coil dimensions and the lumped resistance value are found by optimization.

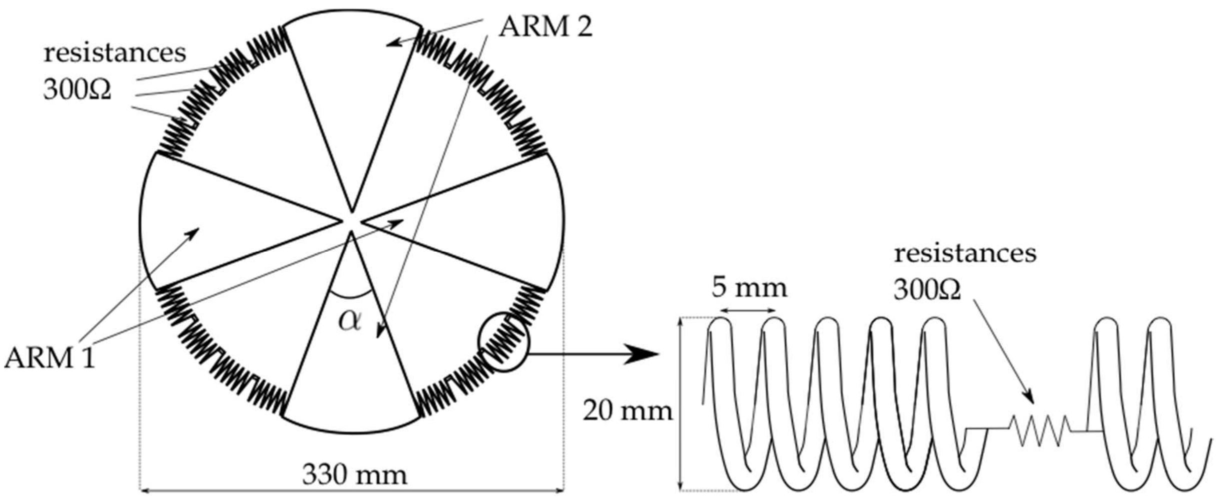

Fig. 1 - Antenna design and dimensions of the coil.

Ferrite tiles are used close to the radiating element to reduce the back radiation and to optimize the impedance matching at low frequencies. A commercially available ferrite, with a thickness of 7 mm, was used. The complex permeability of the ferrite tiles from 150 MHz to 800 MHz are summarized in Table 1. The real and imaginary parts of the permeability decrease respectively from 7 and 50 at 150 MHz to 1.9 and 12 at 800 MHz. Furthermore, the dielectric constant is close to 16 between 10 MHz and 1000 MHz. An octagonal absorbing surface, as shown in Fig. 2, is placed 15 mm under the printed antenna. This geometry is obtained by cutting the corner of a 100 mm x 100 mm ferrite tile. A 350 mm diameter circular ground plane is set at 150 mm ($\lambda_{LF}/13$ at lowest operating frequency) of the antenna. The simulation results, including frequency-dependent properties of ferrite, were performed with the CST Microwave Studio® Transient Solver. The Fig. 3 represents a schematic view of the proposed antenna.

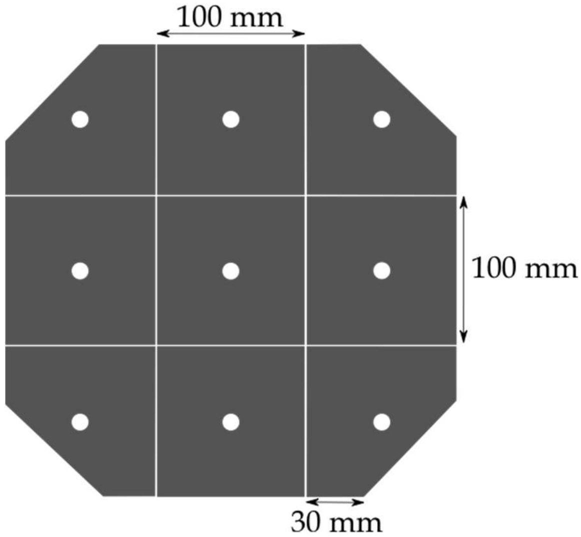

Fig. 2 - Geometry of the absorbing surface.

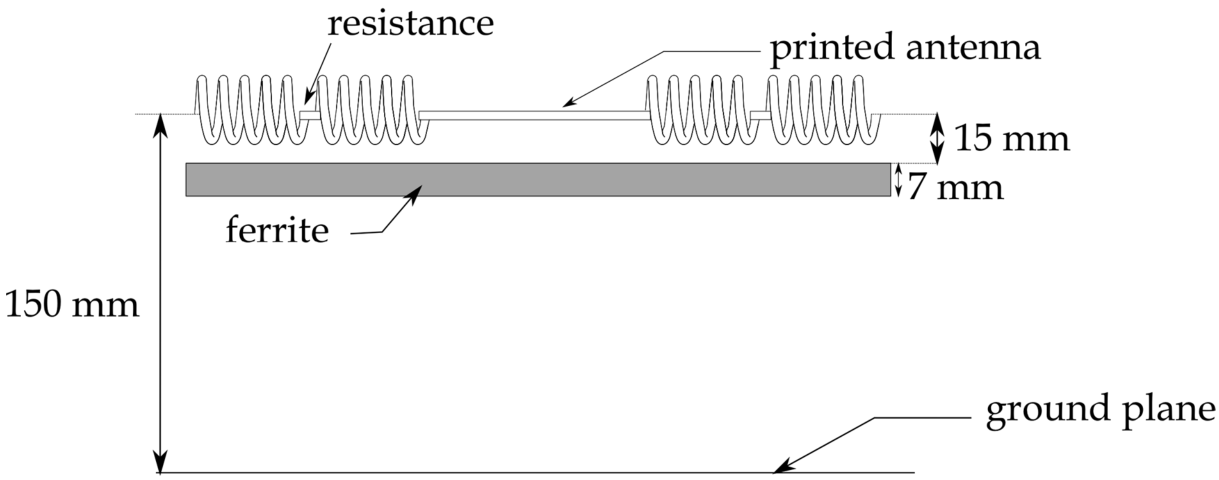

Fig. 3 - Side view of the proposed antenna.

Frequency (MHz)	150	300	450	600	800
Real part	7	3	2.5	2.1	1.9
Imaginary part	50	26	20	15	12

Table 1 - Complex permeability of the ferrite tiles between 150 MHz and 800 MHz.

3 Theoretical and Measurement Results

A prototype of the proposed antenna was fabricated, as illustrated in Fig. 4. The two orthogonal polarizations will be named ARM 1 or ARM 2. Each antenna is fed by an impedance transformer. The 50 Ω unbalanced input pulse is transformed to 200 Ω balanced by the radio frequency (RF) pulse transformer TP-103 by M/A-COM. It was chosen because it provides low insertion loss over a wide frequency band. When one antenna was being measured, the other antenna was terminated with a 50 Ω load connected to the input port of the impedance transformer. Finally, four spacers keep the antenna at 150 mm of the ground plane, as shown in Fig. 5. The total weight of the antenna is about 5.6 kg.

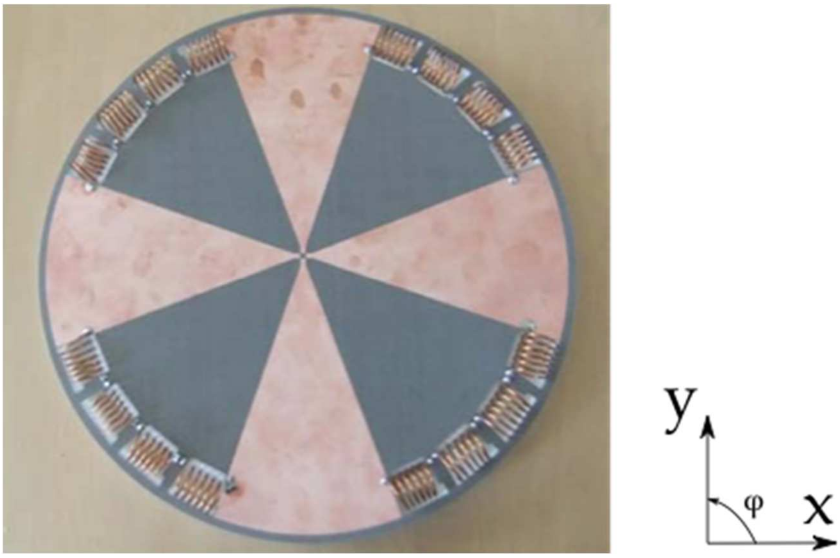

Fig. 4 - The proposed dual-linear polarized UWB antenna.

Fig. 5 - Outdoor measurement of the proposed antenna.

3.1 Antenna Impedance and Isolation between the two ports Measurements

Fig. 6 exhibits the measured and simulated VSWR of the proposed antenna for each arm between 150 MHz and 800 MHz. The VSWR is found lower than 3:1 from 150 MHz to 800 MHz both in simulations and measurements. The lumped resistances on the coiled crown allow an improvement on the VSWR by absorbing stray reflections on the feed. We noticed some discrepancies due to feeding problem coming from the impedance transformer which were not considered in simulation (use of a discrete port). Approximations in the realization of the coils can also explain these discrepancies.

We also noted that the two arms behave the same below 500 MHz. From these results, it can be concluded that the bandwidth of this antenna is close to one decade with a diameter and a height respectively limited to 330 mm and 150 mm for the lowest frequency of 150 MHz which corresponds to an antenna of only $\lambda_{LF}/6$ diameter and of only $\lambda_{LF}/13$ height. An antenna is considered as electrically small when the diameter of the radiating element is lower than λ_{LF}/π , where λ is the free space wavelength [12]. As a result, the proposed antenna can be considered as electrically small at frequencies below 290 MHz.

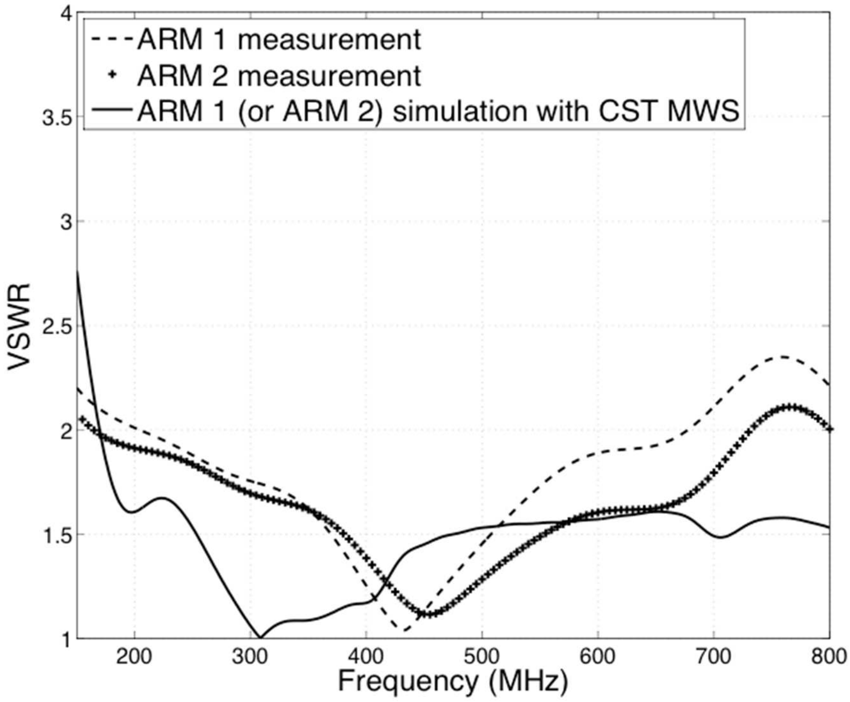

Fig. 6 - Measured and simulated VSWR of the proposed antenna.

Fig. 7 shows the measured coupling between the two input ports over the whole bandwidth of the fabricated antenna. We noticed a good isolation between the two arms greater than 30 dB.

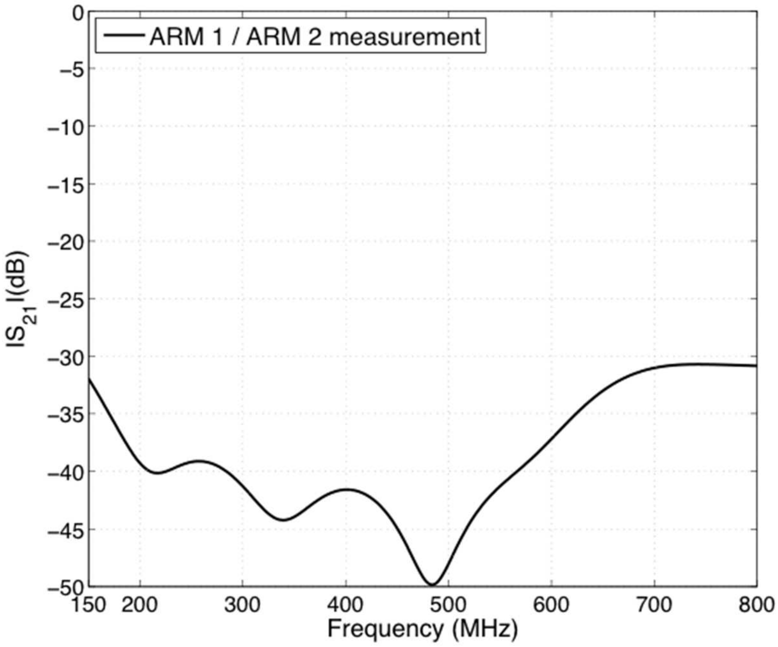

Fig. 7 - Measured isolation between the two arms of the proposed antenna.

3.2 Realized Gain

In Fig. 8, it is clear that the use of a coiled crown on a bow-tie antenna provides better realized boresight gain, by slowing down the currents, below 220 MHz. Consequently, with a coiled crown, it is possible to achieve -10 dBi gain down to 140 MHz, whereas this is obtainable only at 190 MHz with an untreated crown. We also noticed a lower realized boresight gain from 220 MHz due to the current absorption of resistances.

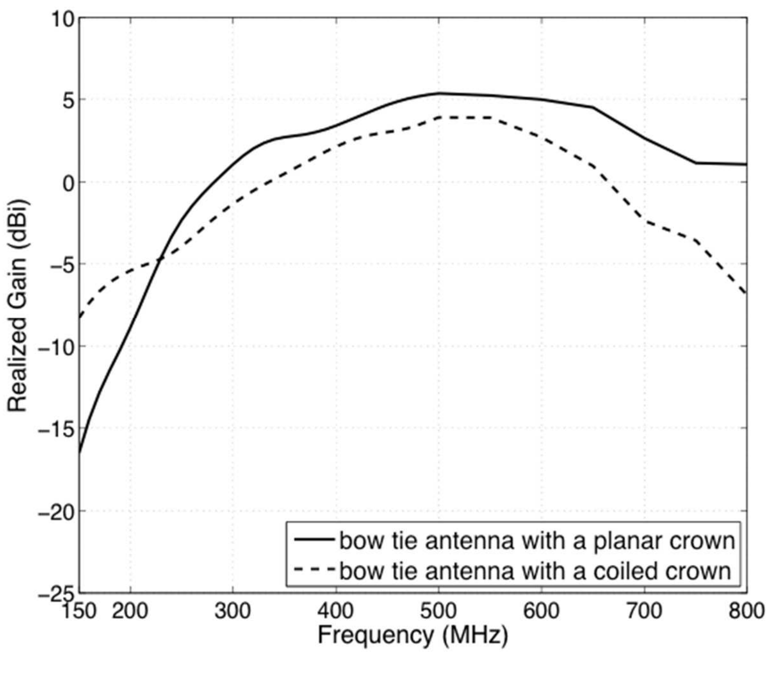

Fig. 8 - Gain performance of the 330 mm bow tie antenna with or without a coiled crown.

Fig. 9 shows the simulated and measured realized boresight gain for the co-polarization of each of the two arms. We noticed a good agreement between measurements and simulations below 750 MHz. Furthermore, it shows that the co-polarization gain level of each of the arms is nearly the same over the whole frequency range. The proposed antenna achieves a -10 dBi gain above 140 MHz and a 0 dBi gain above 340 MHz. The weak gain at low frequencies is mainly due to the size of the antenna with reference to the wavelength. Moreover, the high back radiation at low frequencies can also explain this result. Nevertheless, regarding to VHF/UHF operations, the gain levels are acceptable because the wave propagation at these frequencies is better. The total efficiency, obtained in simulation on CST, of the antenna is also plotted on Fig. 9. We can note that the total efficiency is about 10% at 150 MHz and increases to 55% at 500 MHz. The lumped resistances and the ferrite contribute to the low efficiency by absorbing currents.

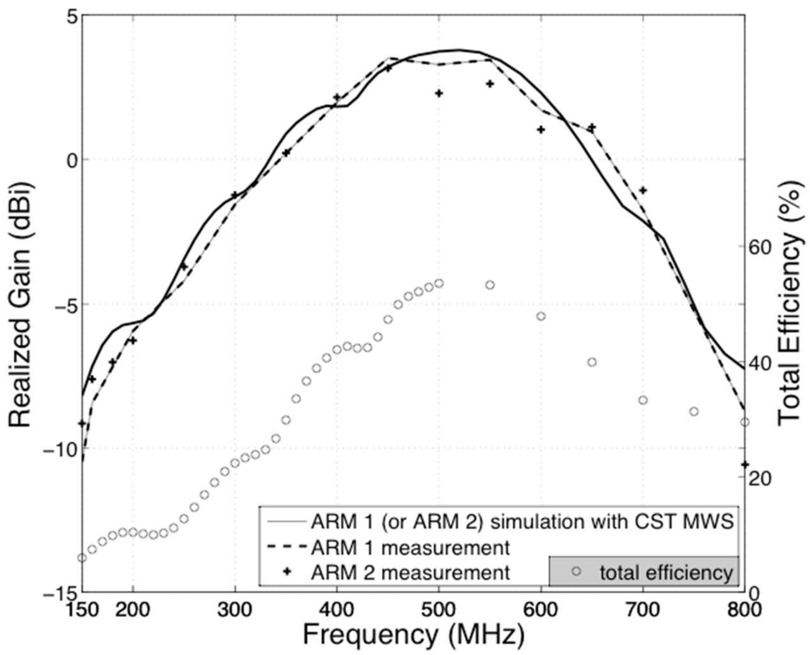

Fig. 9 - Measured and simulated realized boresight gain of the proposed antenna.

3.3 Radiation Patterns

Fig. 10 presents the normalized measured and simulated radiation patterns for Arm 1 of the proposed antenna in the E-plane. We noticed a good agreement between computed results and measurements between 150 MHz and 700 MHz. We also observed a half power beamwidth greater than 100° at 150 MHz and decreasing to 65° at 700 MHz. Furthermore, the measured front-to-back ratio is greater than 10 dB between 300 MHz and 700 MHz. The discrepancies observed on the front-to-back ratio between simulations and measurements are due to the presence of the metallic mast placed behind the antenna. The cross-polarization isolation is found to be greater than 7 dB at 150 MHz and greater than 15 dB above 300 MHz within the -3 dB beamwidth of the antenna. The reason for the only 7 dB polarization isolation at low frequencies is due to approximation during the fabrication of the coils. The winding pitch is not perfectly equal to 5 mm for each coil. It is expected that more than 25 dB polarization isolation can be achieved with an improved fabrication procedure.

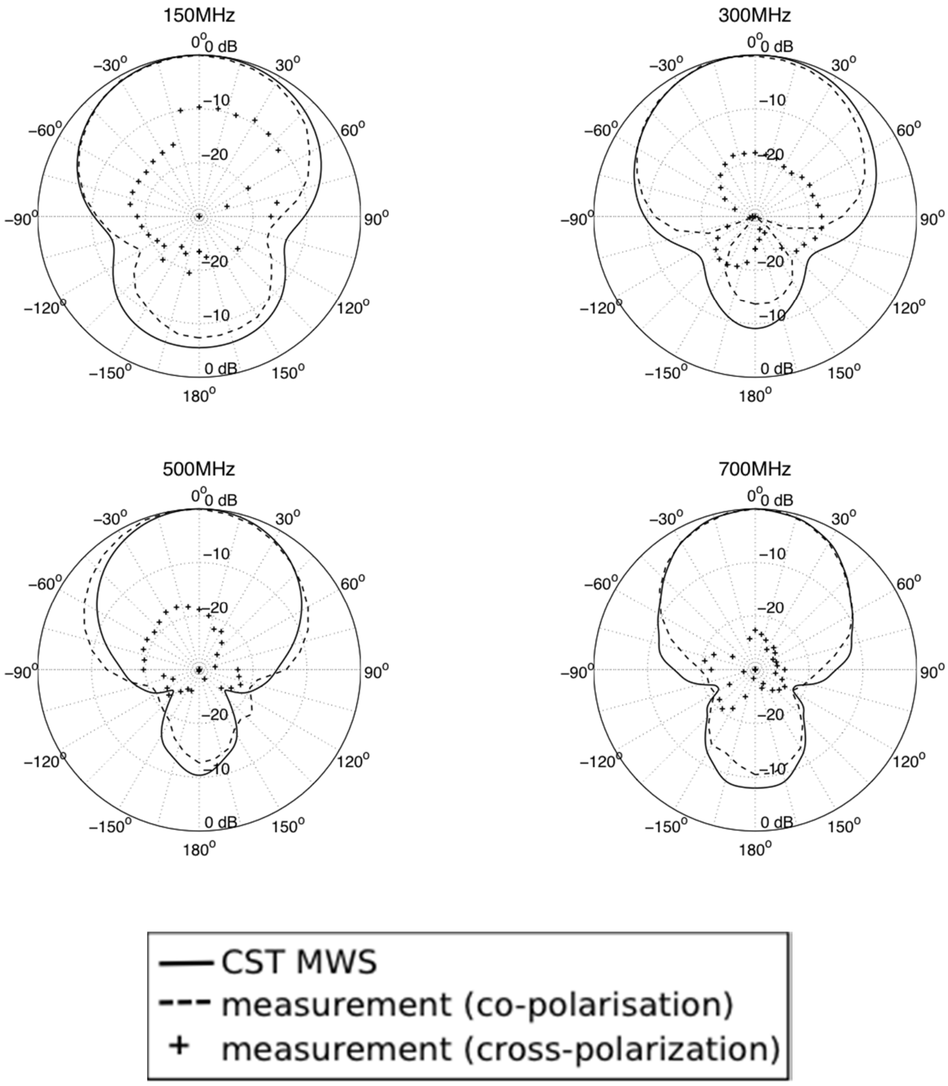

Fig. 10 - E-plane radiation patterns for Arm 1 of the proposed antenna between 150 MHz and 700 MHz (at $\phi = 0°$, E_θ : co-polarization; E_ϕ : cross-polarization).

The normalized measured and simulated radiation patterns for Arm 1 of the antenna in the H-plane are plotted in Fig. 11. Simulations and measurements are found to be in good agreements. We also noticed that the 3 dB beamwidth is greater in the H-plane than in the E-plane of the antenna. Indeed, a half power beamwidth greater than 115° below 700 MHz is achievable in the H-plane of the antenna. The proposed antenna is directional with a measured front-to-back ratio greater than 10 dB over the whole frequency range. Finally, a 15 dB cross-polarization isolation in the 3 dB beamwidth of the antenna is possible between 150 MHz and 700 MHz.

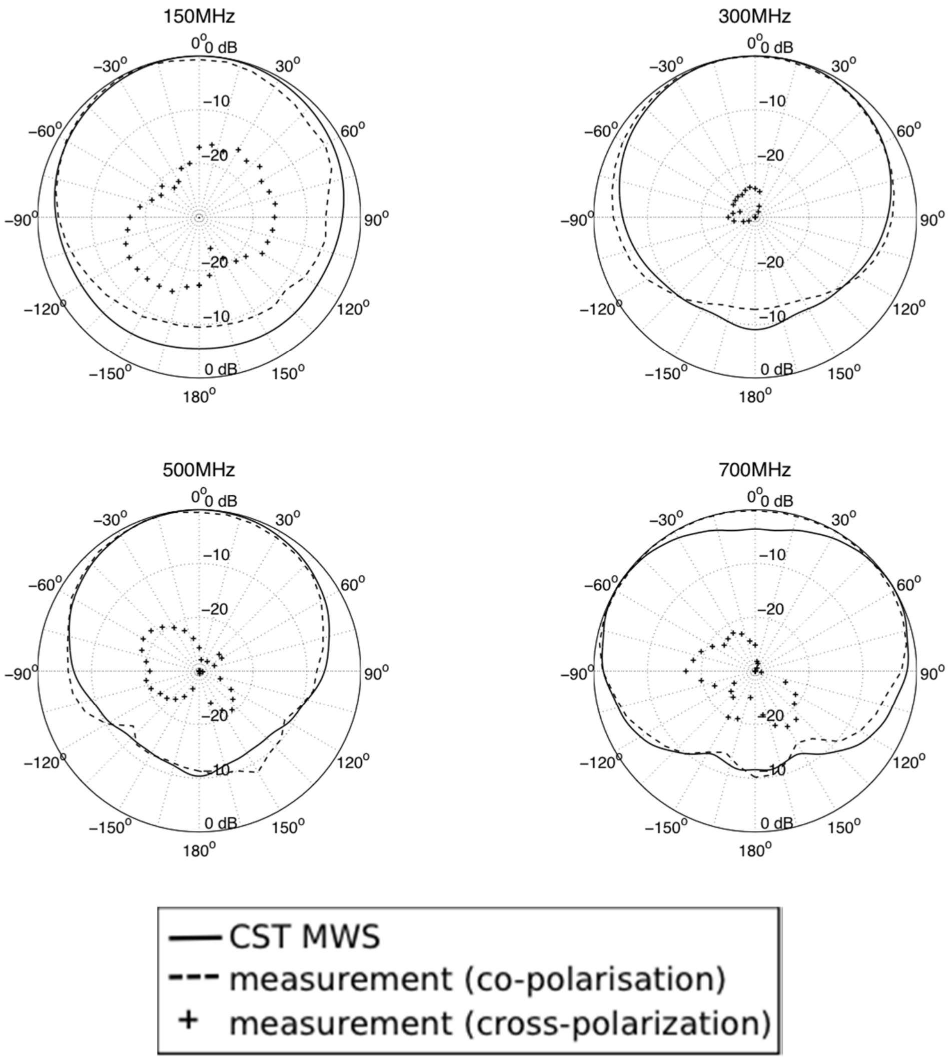

Fig. 11 - H-plane radiation patterns for Arm 1 of the proposed antenna between 150 MHz and 700 MHz (at $\phi = 0°$, E_ϕ : co-polarization; E_θ : cross-polarization).

4 Conclusion

A low-profile dual-linear polarized antenna has been investigated, showing a wide impedance bandwidth. The antenna is based on a bow tie antenna associated to a coiled crown and lumped resistances. Ferrite tiles have been added to improve the VSWR and the front-to-back ratio at low frequencies. The vertical size and the diameter of the structure is respectively close to $\lambda_{LF}/6$ and $\lambda_{LF}/13$, where λ_{LF} corresponds to wavelength at the lowest frequency of the covered bandwidth. Thanks to a coiled crown, a significant improvement of the antenna gain is achievable at low frequencies. Simulation and measurement results are in good agreements and show unidirectional radiation patterns in both the E-plane and H-plane.

REFERENCES

[1] V. Rumsey, “Frequency independant antenna,” National IRE Convention Record, vol. 1, pp. 114–118, 1957.
[2] R. DuHamel, “Dual polarized sinuous antennas,” US Patent 4,658,262, April, 14th 1987.
[3] D. Filipovic and J. Volakis, “Design and demonstration of a novel conformal slot spiral antenna for VHF to L-band operation,” IEEE
Antennas and Propagation Society International Symposium, vol. 4, pp. 120 –123, 2001.
[4] B. Kramer, M. Lee, C.-C. Chen, and J. Volakis, “Miniature UWB conformal aperture with volumetric inductive loading,” IEEE Antennas and Propagation Society International Symposium, pp. 3693 –3696, July 2006.
[5] B. Kramer, M. Lee, C.-C. Chen, and J. Volakis, “Design and performance of an ultrawide-band ceramic-loaded slot spiral,” IEEE Transactions on Antennas and Propagation, vol. 53, no. 7, pp. 2193 – 2199, July 2005.
[6] H. Nakano, “A meander spiral antenna,” IEEE Antennas and Propagation Society International Symposium, vol. 3, pp. 2243 – 2246, June 2004.
[7] B. Kramer, C.-C. Chen, and J. Volakis, “Size reduction of a low-profile spiral antenna using inductive and dielectric loading,” IEEE Antennas and Wireless Propagation Letters, vol. 7, pp. 22 –25, 2008.
[8] J. Volakis, C.-C. Chen, J. Halloran, and S. Koulouridis, “Miniature VHF/UHF conformal spirals with inductive and ferrite loading,” IEEE Antennas and Propagation Society International Symposium, pp. 5 –8, June 2007.
[9] F. Erkmen, C.-C. Chen, and J. Volakis, “UWB magneto-dielectric ground plane for low-profile antenna applications,” IEEE Antennas and Propagation Magazine, vol. 50, no. 4, pp. 211 –216, August 2008.
[10] I. Tzanidis, C.-C. Chen, and J. Volakis, “Smaller UWB conformal antennas for VHF/UHF applications with ferrodielectric loadings,” IEEE Antennas and Propagation Society International Symposium, pp. 1 –4, July 2008.
[11] I. Osaretin, A. Torres, and C.-C. Chen, “A novel compact dual-linear polarized UWB antenna for VHF/UHF applications,” IEEE Antennas and Wireless Propagation Letters, vol. 8, pp. 145 –148, 2009.
[12] H. Wheeler, “Fundamental limitations of small antennas,” Proceedings of the IRE, vol. 35, no. 12, pp. 1479 – 1484, December 1947.