Analysis of Omnidirectional Antennas with Radome Operating in LMDS Band for Signals of Digital TV

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Abstract— **This work considers the use of dual-reflector antennas for omnidirectional coverage in a LMDS system base station to operate with the distribution of digital TV signals. We investigate the performance of omnidirectional antenna with and without dielectric radome. Numerical simulations based the method of moments are presented to illustrate the usefulness of the omnidirectional antennas to operate in LMDS systems. The analyses are conducted for a 20% bandwidth. It is used a radome with thickness equal to λ/2 and relative permittivity equal to 2.08. The analyses intend to demonstrate the radome influence in the antenna behavior across the operation band and to identify the best radome thickness.**

Keywords-Method of moments; omnidirectional reflector antennas; radomes; LMDS, digital TV

I. INTRODUCTION

The recent growth of internet-related applications and the introduction of digital TV by satellite with new interesting and interactive possibilities have stimulated of development of new radio-based technologies such as local multipoint distribution systems (LMDS). This technology has the advantage of a high-capacity of downlink and can be shared by many users in a flexible manner. LMDS is the broadband wireless technology with cellular architecture that provides flexible high capacity connections. The systems employ a point-to-multipoint broadcast downlink and can be used to deliver digital TV signals, high-speed data, voice signals or video. The frequency allocations are in the 28–29 GHz band in the United States [1]. The European Standard for Antennas for Point-to-Multipoint fixed radio systems proposes the use of several frequency bands (from 11 GHz up to 60 GHz), for which it makes sense the use of reflector antennas as a feasible solution [2],[3].

Many antennas have been designed for these wireless point-to-multipoint applications based on the cellular radio concept. The cell base-station antenna is required to give uniform coverage in the azimuth plane, which is achieved either with an omnidirectional antenna at the center of the cell or some sectorial coverage antennas. In [4] some antennas configurations are investigated for LMDS systems operation. For terminal multiflare horns with dielectric lens and shapped Gregorian splash reflectors are presented. For base stations omnidirectional single and dual shapped reflector solutions are described. An omnidirectional antenna consisting of an axially-fed dual-rotationally symmetric reflector configuration was proposed [5] as an inexpensive solution for areas of limited traffic. In [6] a reflector antenna is presented as a feasible solution for LMDS systems base station with a reconfigurable number of sectorial beams. The antenna is an improved version of the hourglass reflector antenna.

LMDS systems band frequency operation requires the use of reflector antennas as a feasible solution. Reflector antennas can yield compact designs capable of providing the wide bandwidth required. Omnidirecional dual-reflector antennas are more compact than single reflectors [7]-[10] and may reduce the feed return loss [8],[9]. There are four different types of axis-displaced dual-reflector antennas for omnidirectional coverage: OADC (omnidirectional axis-displaced Cassegrain), OADG (Gregorian), OADE (ellipse), and OADH (hyperbola) [7]-[10]. Among them, the OADC and OADE can lead to compact geometries [8]-[10].

Radomes are used to protect antennas from a variety of environmental and aerodynamical effects and may be designed to support the subreflector. However, they create undesirable blockage due to interactions of the antenna fields with the radome. Needless to mention, the radome affects the antenna pattern and the feed return loss across the bandwidth. A careful analysis of the antenna-radome system is thus appropriate [11]. Several techniques have been developed for the analysis of antenna-radome structures to provide accurate design tools. Surface integral equations, numerically evaluated by the method of moments (MoM), are one of the most accurate analysis tool.

As OADC antenna configuration leads to compact geometries, we investigate this antenna, with and without dielectric radome, to operate in LMDS systems. The antenna geometry, illustrated in Fig. 1, is basically the same studied in [12]. However now we used a more efficient coaxial horn and different radome thickness are analyzed in a different operation band. In this work we intend, beyond to demonstrate the radome influence in the antenna behavior across the operation band, also to identify the best radome thickness. The accurate analysis is based on the electric (EFIE) and magnetic (MFIE) field integral equations, numerically evaluated by the method of moments (MoM) technique. The OADC antenna configuration is excited by a TEM coaxial horn and is used a radome with relative permittivity equal to 2.08.

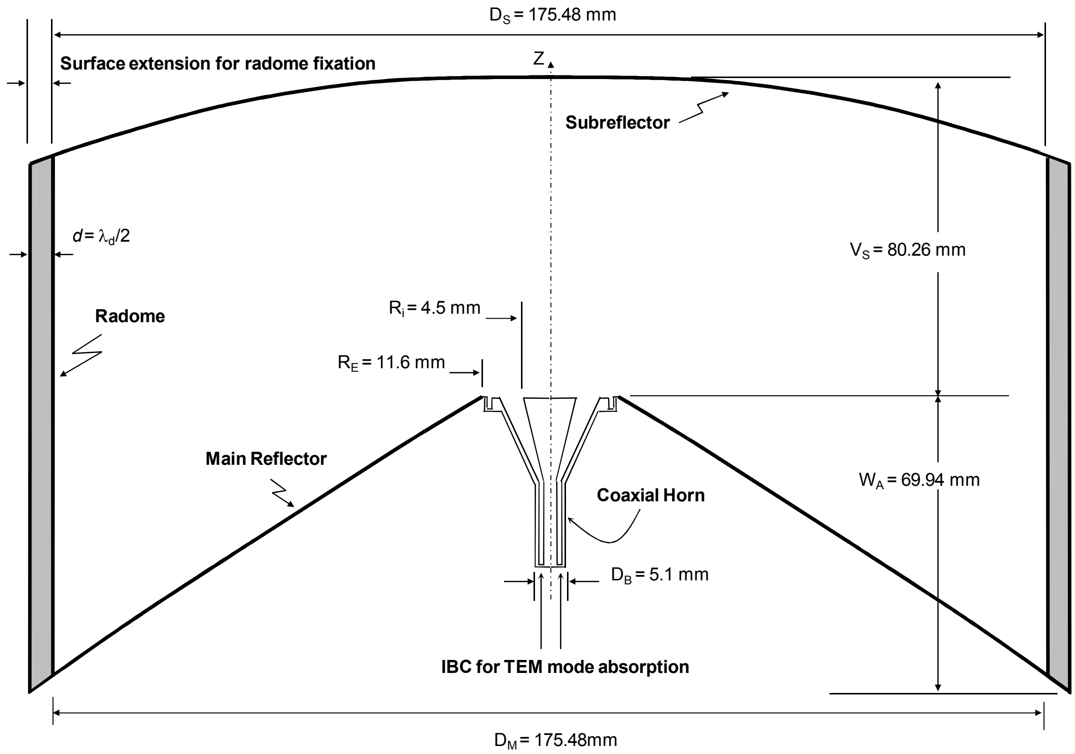

Figure 1 Omnidirectional antenna geometry (OADC)

II. SURFACE INTEGRAL EQUATIONS

MoM solutions involving the EFIE and MFIE lead to many different formulations [13], [14]. The EFIE is the choice for open conducting shells. For closed conducting surfaces the combined field integral equation (CFIE) avoids spurious resonances [14]. The CFIE is a linear combination of EFIE and MFIE. For dielectric bodies, EFIE and MFIE can be linearly combined in several forms [13]. One of the most adopted combinations are Müller and PMCHWT formulations [13].

Present numerical evaluation of the formulations is performed by the MoM technique. Triangular basis functions (TBF) are employed for the equivalent current representation and Galerkin's method is adopted to numerically evaluate the MoM coefficients. All integrals appearing in the MoM full-matrix elements are evaluated by Gaussian quadratures with appropriate singularity treatment [15].

III. OMNIDIRECTIONAL ANTENNA WITHOUT RADOME

The OADC antenna shown in the Fig. 1, without the radome, is analyzed for operation in a LMDS system across the operation band of 26 to 34 GHz. The antenna dimensions are described in Fig. 1 and were chosen for $D_s = 17.57\lambda_c$, $D_M = 17.57\lambda_c$, $V_s = 8.03\lambda_c$, $W_A = 7\lambda_c$, $D_B = 0.255\lambda_c$, $R_i = 0.45\lambda_c$ and $R_E = 1.16\lambda_c$, where λ_c is the wavelength in the vacuum for central frequency of de band, 30 GHz. It is used the horn presented in [16]. The radiation patterns obtained from the MoM analyses across the operation band are illustrated in Fig. 2 and the Fig. 3 shows the maximum gain and the angle where maximum gain occurs (MGA). As it can be verified the overall antenna performance (levels and spatial distribution of main lobe and sidelobe) is not significantly affected across the operation band. This fact enables this antenna configuration for operation in LDMS systems, in principle.

IV. OMNIDIRECTIONAL ANTENNA WITH RADOME

In this section the electrical performance of the OADC configuration with radome, illustrated in Fig. 1, is investigated for operation in the same frequency range. It is employed a radome with relative permittivity of 2.08. The radome thickness (*d*) is chosen for minimal reflection (i.e, the radome is a half-wavelength, λ_d, window), where λ_d is the wavelength in the dielectric [15]. In this work, three different radome thickness (*d*) are investigated, as described in Table 1. These Three values were calculated using wavelength in the dielectric radome at 26, 30 and 34 GHz, respectively.

The radiation patterns of the antenna at 26, 30 and 34 GHz are shown in Figs. 4—6, respectively. These demonstrate that antenna electric behavior (levels and spatial distribution of main lobe and sidelobe) is not significantly modified by the radome presence. Tables 2 and 3 and Fig. 7 show the maximum gain and angle where maximum gain occurs (MGA), respectively, at 26, 30 and 34 GHz for the radome thickness *d* presented in Table 1. It can be observed that across the operation band the antenna characteristics are kept without important modifications.

Fig. 8 illustrates the feed return loss across the bandwidth. The oscillatory behavior of the return loss across the band is expected and caused by the electromagnetic coupling among

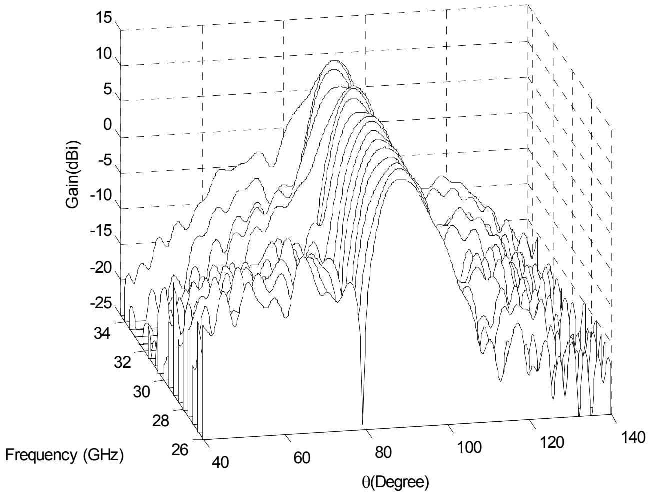

Figure 2. Radiation patterns: OADC antenna whitout radome operating in the LDMS system (26 to 34 GHz)

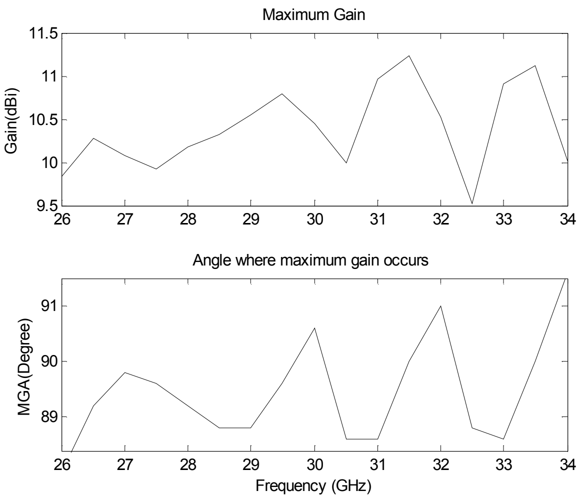

Figure 3. OADC antenna whitout radome operating in the LDMS system (26 to 34 GHz): a) Maximum gain b) AMG

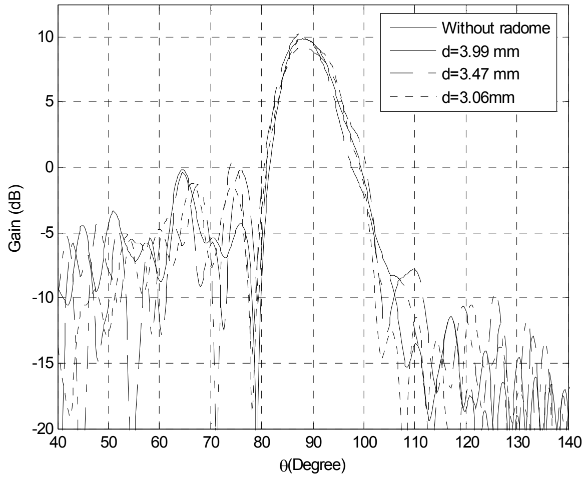

Figure 4. Radiation pattern: OADC antenna with radome at 26 GHz

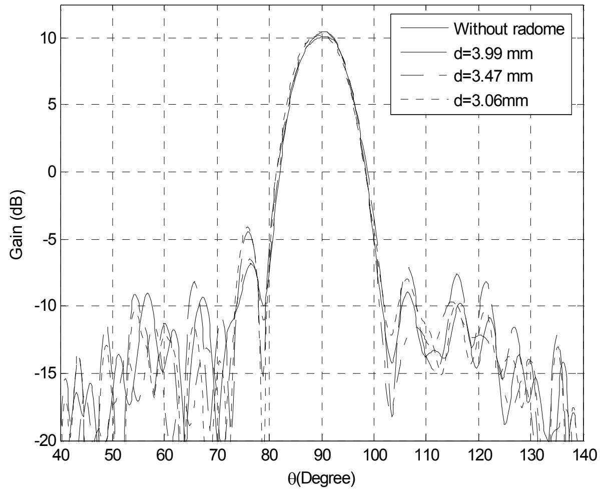

Figure 5. Radiation pattern: OADC antenna with radome at 30 GHz

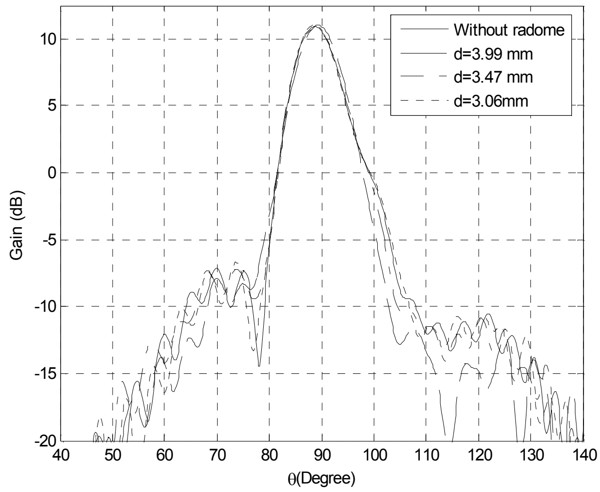

Figure 6. Radiation pattern: OADC antenna with radome at 34 GHz

TABLE I. RADOME THICKNESS

Frequency (GHz)	λ_d (mm)	Radome thickness *d* (mm)
26	11.53	3.99
30	9.99	3.47
34	8.82	3.06

TABLE II. OADC ANTENNA WITH RADOME: MAXIMUM GAIN (DBI)

Radome thickness *d* (mm)	Frequency (GHz)		
	26	**30**	**33**
3.99	10.28	10.11	9.97
3.47	9.28	10.49	10.05
3.06	9.90	10.15	9.98

TABLE III. OADC ANTENNA WITH RADOME: MGA

Radome thickness *d* (mm)	Frequency (GHz)		
	26	**30**	**34**
3.99	87.8	90.6	90.6
3.47	88	90.2	91.8
3.06	88	89.8	91.4

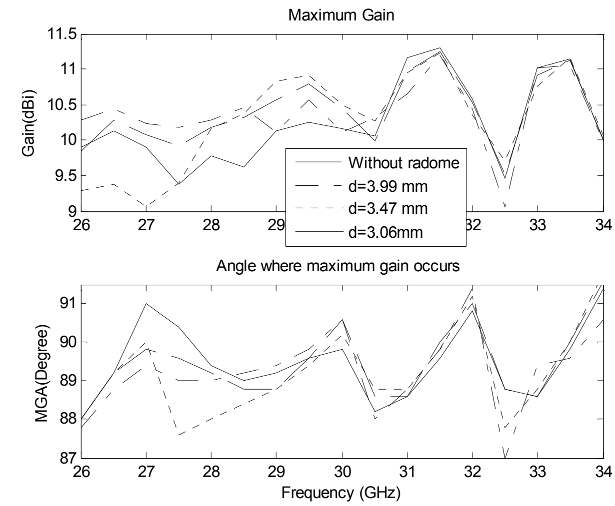

Figure 7. OADC antenna whit radome operating in the LDMS system (26 to 34 GHz): a) Maximum gain b) AMG

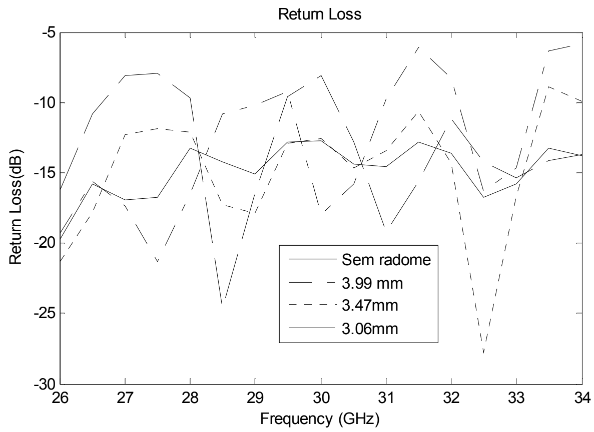

Figure 8. Return Loss: OADC antenna whit radome.

feed structure, reflectors, and radome. As it can be verified at frequencies of 26, 30 and 34 GHz the value of return loss for antenna without radome is approximated equal to antenna with radome with thickness equal to 3.99, 3.47 and 3.06 mm, respectively. This fact demonstrates that for frequency for which the radome was specified (frequency of radome sintony - FRS) it is almost invisible for antenna system (i.e., the reflections are minimum). When the frequency deviates from the FRS, the feed return loss increases, as expected. Across the operation band, the smallest return-loss variation occurs for the radome with FRS in the center frequency (30 GHz). Antennas with a FRS radome in the extremes of the operation band present return loss above −10dB for some frequencies; whereas for the radome with FRS at 30 GHz the return loss peak is −8.5dB, remaining below −10dB at most of the operation band. So, from the return loss point of view, the best radome thickness is equal to 3.47 mm.

V. CONCLUSION

This work studied dual-reflector antennas for omnidirectional coverage in a LMDS system to operation with signals of digital TV. The performance of omnidirectional antenna with and without dielectric radome was investigated. The rigorous analysis was based on electric (EFIE) and magnetic (MFIE) field integral equations, numerically evaluated by the MoM technique. The antenna systems were excited by an omnidirectional TEM coaxial horn. It was verified that the electrical performance of the analyzed antennas was not significantly modified across a 20% operation bandwidth. From the retrun loss point of view, considering the frequencies values analyzed across the operation band, the best radome thickness is equal to 3.47 mm ($\lambda_d/2$ where λ_d is the wavelength in the dielectric for central frequency of the operation bandwidth).

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