Applications of wire media as antenna radomes

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Abstract

The paper presents a recent development of wire media for antennas and communication applications. In order to conceal the antenna or to keep its interface coincident with a vehicle wall, the antenna is placed within the metal cavity. Characteristic distortions, expected from cavity influence, is decreased by a wire media block, which translates near field of the antenna towards the outer interface of the cavity. Theoretical predictions and measured results have been compared and a reasonable agreement between them has been obtained. The radome is intrinsically multi-band. The structure both hides an antenna from external mechanical and environmental influence, and transmits its near-field onto outer interface in contrast to conventional radomes which alter antenna characteristics and have to be taken into account during design process.

1. Introduction

Extremely anisotropic metamaterials are uniaxial media with very large permittivity along the anisotropy axis. These materials, which are usually created artificially, offer a unique opportunity to eliminate diffraction effects. The electromagnetic waves in these media do not experience cut-off and travel strictly along the axis of anisotropy without any diffraction effects. Structures with extreme anisotropy in microwave range can be constructed using arrays of metallic rods [1]. Such waveguiding property allows one to construct transmission devices capable of near-field transportation to arbitrary distances [2, 3, 4, 5]. Their principle of operation [6] is based on the transformation of the complete spectrum of spatial harmonics generated by the source, including evanescent waves, into propagating eigenmodes of the metallic array and tuning the thickness of the structure to obey Fabry-Perot resonance.

In the paper, a block of wire media is proposed to be utilized simultaneously as a concealing, imaging and damage preventing device. Unlike conventional radomes or mechanical defence this device is operating not only with propagating spatial harmonics of the source but also with its near-field. In general, its operation can be shortly described as a transfer of near field antenna distribution towards the outer interface. It can be important if antenna hidden within building walls or placed in a moving vehicle when it is preferable not to alter aerodynamics performance of the vehicle.

To prove the concept series of experiments have been undertaken. The experimental set-up is shown in Fig. 1. The measurement results are demonstrated and discussed in the paper. Purposely, simulations have been omitted as wire medium itself has been comprehensively theoretically and numerically investigated in papers mentioned above, whilst its multi-frequency capabilities have been recently experimentally proven and published, e.g. [7].

ISBN 978-952-67611-2-1

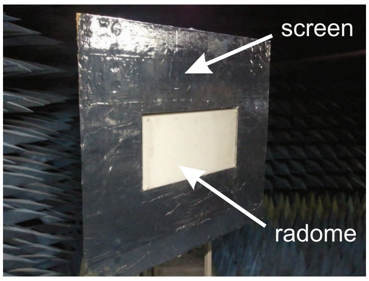

Fig. 1: Antenna radome formed by block of wire medium hides an antenna in a metallic cavity.

2. Measurements

It is well known that antennas placed in a metal cavity would alter their performances due to multiple reflection and resulting interference within the cavity, e.g. [8]. To demonstrate this effects and how it can be avoided using dielectric wire media, the authors manufactured a half wavelength dipole operating at 900 MHz and a metal cavity where the dipole is supposed to be inserted. The dipole placed within the cavity demonstrates the influence of metal walls on dipole characteristics. The dimensions of the cavity are $50 \times 25 \times 25$ cm. The antenna is then placed within the cavity at approximately a quarter wavelengths from the back metal wall to avoid major distortion of antenna's return loss. Accordingly to expectations, measurement results show significant alteration of radiation pattern. Radiation patterns were measured in the azimuthal plane. For an ordinary vertical dipole it results in omnidirectional radiation. However, radiation patterns are severely altered due to a presence of the cavity.

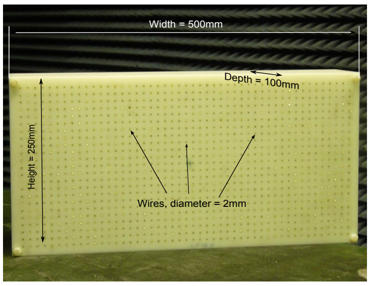

Fig. 2: Acetal block loaded with wire media.

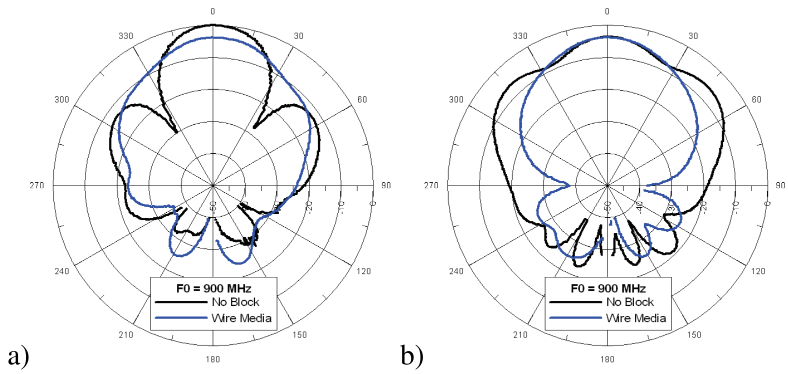

Fig. 3: Comparison of radiation patterns of the half wavelength dipole placed within the metal cavity with and without the dielectric block loaded by wire media: vertical (a) and horizontal (b) orientations.

The next step is to put a dielectric block loaded with wire media in front of the antenna within the cavity where the block interface is coplanar with the front interface of the cavity. The dielectric block is made of acetal. The thickness of the block is approximately a half-wavelength in the acetal ($\varepsilon_r = 3.8$) at the first Fabry-Perot resonance of the structure. Brass wires (diameter 2mm) are inserted at the distance of 1 cm. The block is demonstrated in Fig. 2. Previous measurements results, e.g., [7], clearly showed that the block is also operating at the second Fabry-Perot resonance.

The set-up is supposed to bring the near field of the antenna onto the front interface of the cavity. The main objective of the presented research is to demonstrate a capability of wire media to restore expected antenna characteristics while an antenna is placed within a cavity of arbitrary dimensions. Indeed, ground plane, presented at the outer interface will alter overall performance of the antenna, but one can eliminate additional distortions caused by a presence of the cavity. In accordance with the prediction, introduction of a dielectric loaded wire media block results in dramatic change of radiating field. In order to make it clear, radiation patterns of the antenna obtained in two different experiments mentioned above, are placed together and compared at the central frequency of the investigated frequency band. These results are shown in Fig. 3. It is worth to mention that the measurements undertaken have been performed only in the azimuth plane which was parallel to the longer side of the cavity, otherwise, to the horizontal plane. That was due to dimensional restriction in the anechoic chamber where experiment took place.

3. Conclusions

The results presented have proved that dielectric wire media can be used in practical applications such as radomes, antenna covers, as well as hiding antennas in cavities (including metal one). Furthermore, it has been shown that antenna performance are not significantly affected which means that antennas can be placed behind wire media without extra efforts to match or re-design them. It is intrinsically multi-frequency operational. The media can be found useful for communication and security/military applications whilst at higher frequencies, e.g., Ku- or Ka-bands, decreased media dimensions can offer attractive solutions for installing antennas on trains, cars, ships, etc. without affecting aesthetic appearance and aerodynamic performance of vehicles.

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