Impact of Flat Radomes on Amplitude-Only Direction Finding Performance

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***Abstract*—We investigate the impact of placing a thin flat radome in front of an amplitude-only direction finding (AODF) antenna system. The considered system consists of two identical Ka-band, air-filled horn antennas squinted off boresight by 30° for direction finding (DF) error within ±0.82°/dB over a field-of-view (FoV) from -20° to +20°. Computational results with various radome materials, thicknesses, and placements indicate that it is possible to maintain excellent DF performance if radome is properly designed and located.**

Keywords—amplitude only direction finding, antenna radome, horn antennas, millimeter-wave antennas.

I. INTRODUCTION

Radomes are often desired to provide mechanical and environmental protection of antenna front-ends in air-borne warfare, communication, and sensing applications. A properly-designed radome should provide the required protection with minimal influence on electrical performance [1]. The design challenge varies with the acceptable compromise between the level of protection and electrical transparency as allowed for a specific application. In amplitude-only direction finding (AODF) systems, any alteration of radiation performance is carried to the DF performance in terms of accuracy, field of view (FoV), and bandwidth. Therefore, a careful radome design is essential in order to avoid any degradation of radiation patterns, such as rippling and beamwidth instability.

In this paper we investigate the effect of thin, flat radomes on AODF antenna system operating in the Ka band (26.5–40 GHz). The system consists of two nearly-sectoral horn antennas squinted off in the H-plane to provide two differential beams suitable for low-error DF over -20°–20° FoV. The plane-wave analysis suggests that lower radome permittivity and thickness entails minimal degradation of radiation and, thus, DF performance. This is computationally validated by full-wave simulation in HFSS [2] with the radome placed flush over horn aperture. However, since the radome exists in the near field of the antenna, it is found that far-field performance can also be controlled by adjusting the separation between the radome and horn aperture. Subsequently, excellent DF performance can be maintained with thicker radome sheets.

II. HORN AND SYSTEM CONFIGURATIONS

Fig. 1 shows the configuration and far-field performance of a stand-alone, nearly H-sectoral horn antenna designed for smooth and stable H-plane patterns over the entire Ka band. By squinting two horns off in the H-plane, two distinctive beams suitable for DF scanning are produced. Fig. 2 shows an AODF front-end system with 30° squinted antennas. The direction finding function (DFF), in dB, is the difference between voltage amplitudes at antenna ports or, alternatively, the difference between realized gains of the generated beams. The quality of DFF is determined by its slope (dB/°), shown in Fig. 3, which is inversely proportional to DF errors (°/dB). As seen, the minimum slope is 0.61 dB/°, which corresponds to a maximum DF error of ±0.82°/dB. The purpose is to maintain similar or close DF performance after radome is introduced.

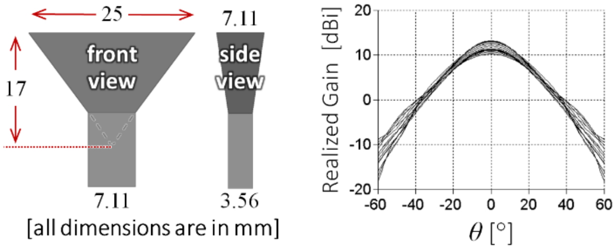

Fig. 1. Configuration of a stand-alone horn antenna (left) and its H-plane radiation patterns (right, 15 curves, 26–40 GHz, 1-GHz step).

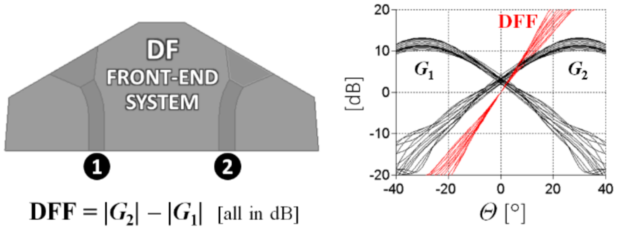

Fig. 2. AODF configuration (left) and DFF performance (right).

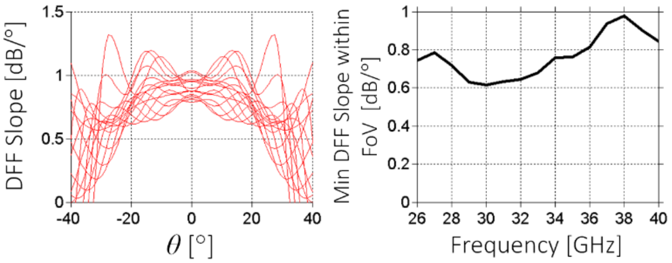

Fig. 3. DFF slope (left) and its minimum in -20°–20° FoV (right).

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III. RADOME PERMITTIVITY AND THICKNESS

Initially, the permittivity and thickness of radome are investigated by means of full-wave simulations with various radome types. Specifically, three, commercially-available, dielectric sheets are considered: Rogers RO5880 (ε_r = 2.2) of 0.125-mm thickness, Kapton (ε_r = 3.5) of 0.125-mm thickness, and SHEERGARD™ SX-12 (ε_r = 2.35) of 0.4-mm thickness. All of these sheets are placed flush to the horn aperture, and computational results are presented in Fig. 4 as curves of minimum DFF slope. It is found that the RO5880 radome maintains the best DF performance compared to the higher permittivity Kapton sheet and to the thicker SX-12 composite. This result is expected because thinner and lower permittivity sheets correspond to lower reflection coefficients as analytically predicted by plane-wave analysis of the stand-alone radome [3]. Fig. 5 shows that the RO5880 sheet reflects much less energy compared to Kapton and SX-12; therefore, the total DF performance resembles more closely to the originally designed system with no radome.

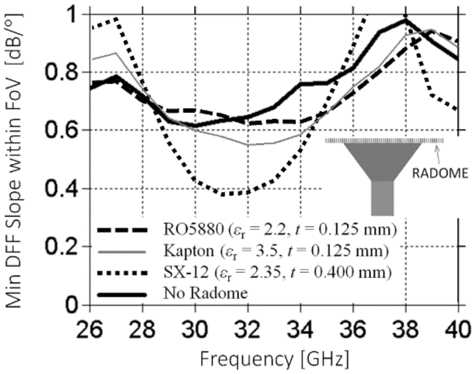

Fig. 4. Minimum DFF slope after applying various radome sheets flush to horn aperture.

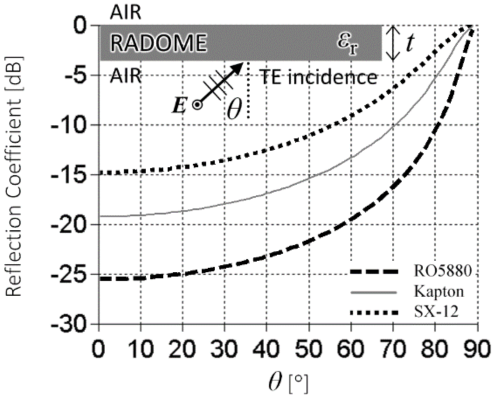

Fig. 5. Reflection coefficient amplitude of a TE plane wave impinging upon various radome sheets.

It is worth to mention that the outcome from the preceding investigation is typically conflicting with mechanical durability that requires more dense radome material (i.e., higher ε_r), higher thickness, or both. Half-wavelength radomes and sandwich arrangements [4] are common choices to increase radome durability at the expense of limiting the bandwidth or field of view, especially for low-error DF applications. Nevertheless, designing radomes based solely on plane-wave analysis ignores the fact that the radome exists at the near field of the antenna and that there might be additional effects of the radome other than energy reflection. Thus, a computational study of radome location is essential in order to choose the best placement of a desired durable radome sheet (such as SX-12).

IV. RADOME SEPARATION

Fig. 6 shows DF performance with an SX-12 radome placed at a separation distance S from the horn aperture. It is evident that performance varies significantly with S, which should not be the case if the plane-wave analysis is an accurate approximation of radome effect. The shown results demonstrate that it is possible to maintain a very high DF accuracy if the SX-12 sheet is placed 5mm away from horn aperture. Despite the added installation complexity (a foam sheet is needed for separation), this radome arrangement presents a more durable choice than a thinner RO5880 flush to the horn. Since radome placement primarily affects the near-field distribution, a new computational study is required when any modification is applied to antenna structure, radome material, or AODF geometry and performance requirement.

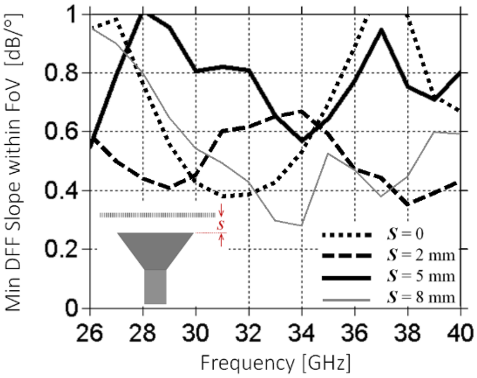

Fig. 6. Minimum DFF slope after applying SX-12 radome at a separation distance S from horn aperture.

V. CONCLUSION

Impact of placing a flat radome in front of an amplitude-only direction finding system is investigated. While thinner, lower-permittivity radomes are preferred, it is still possible to maintain decent DF performance using thicker radomes if it is separated properly from the antenna aperture.

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