A Wideband CPW-Fed Monopole Antenna for High-Temperature Applications

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***Abstract* – In this paper, a coplanar waveguide (CPW) fed monopole antenna is presented on Zirconia Ribbon Ceramic (ZRC) substrate based on Yttria-Stabilized Zirconia (YSZ). The use of this substrate material allows for implementation of patch antenna systems that could withstand harsh environments due to material characteristics. The wideband capability of the design supports various applications within the S-band. The antenna bandwidth is from 1.89 GHz to 3 GHz with a center frequency around 2.45 GHz. The antenna also provides a realized gain higher than 2 dB through the entire band of interest (4 dB at 2.8 GHz) and low cross-polarization.**

I. INTRODUCTION

As the advancement of wireless devices and their applications progress, it is important to produce novel aspects of a usual design to expand their capabilities. One such application could be for extreme circumstances that would include high temperatures. In order to approach this issue, a new substrate has been proposed to implement high-temperature devices. Zirconia Ribbon Ceramic (ZRC) is made of YSZ with high temperature tolerance, smooth surface, moisture resistant, mechanically robust, and low thermal mass properties [1]. Recent publications has demonstrated the suitability of ZRC for implementing functional devices [1-3]. Due to this material's durability and capability of resisting high temperatures, it provides a desirable opportunity of applying this material as a substrate for patch antenna applications. The application of this material, however, requires the understanding of its electrical properties and behavior. This proposed material has a high relative permittivity and a low loss tangent as compared to traditionally available substrates. The high dielectric constant of ZRC along with low loss characteristics allows for realizing efficient wireless systems with smaller form factor. In this study, a wideband patch antenna on ZRC substrate is proposed for high-temperature environments. The antenna operates within 1.89 GHz-3 GHz frequency range, and can be used for WLAN, ISM band, and S-band applications.

II. DESIGN PROCESS

The high-temperature resistant ZRC substrate used for this design has a material thickness of h, 0.23 mm, a dielectric constant, ε_r, of 22 and dielectric loss tangent, tan(δ), of 0.001 [3]. The other substrate parameters are based on a physical sample material that the simulations is based on, with width, W_s, of 40 mm, and length, L_s, of 60 mm.

The geometry of the proposed antenna is displayed in Fig. 1. This image shows a top view of the antenna design. As seen, the radiator has a square-like shape, and it is fed with a CPW line for an increased impedance bandwidth. The design also includes a partial ground plane and the spacing between the ground plane and radiator is determined to be $s = 2\,mm$ to improve the impedance matching of the antenna. Additionally, the dimensions of the radiator and ground plane are optimized as to maximize the radiation of the antenna at its resonant frequency with its wideband capability. The dimensions of the patch, shown in Fig. 1, are as follows, with the patch width, W_p, equal to 32 mm and the patch length, L_p, at 31 mm. The ground plane was composed of two equal parts, each having a length and width, L_g and W_g, of 20 and 18.7, respectfully. The feed, through optimization of patch and ground plane, was determined to have a length, L_f, of 22 mm and a width, W_f, of 2 mm. Finally, the gap, g, between the feed and the ground plane on each side was configured to be 0.3 mm.

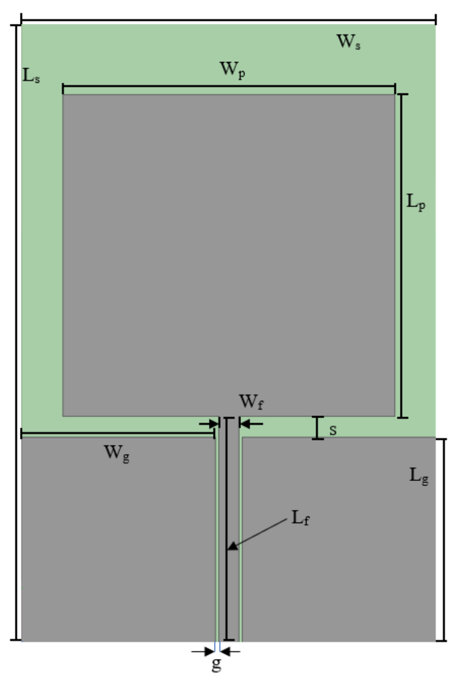

Fig. 1. CPW-Fed Antenna Geometry and Parameter Lengths

III. SIMULATION RESULTS AND DISCUSSION

The CPW-Fed monopole antenna is designed and simulated using ANSYS HFSS. Fig. 2 shows the simulated return loss (S_{11}) of the antenna. As seen, the -10 dB impedance bandwidth is 45% for the frequency range from 1.89 GHz through 3.00 GHz. It also shows a good impedance matching at the center frequency around 2.5 GHz. The peak realized gain is depicted in Fig. 3 for the operating range. The simulated peak gain is over 2 dB through the entire band while it reaches 4 dB around 2.8 GHz.

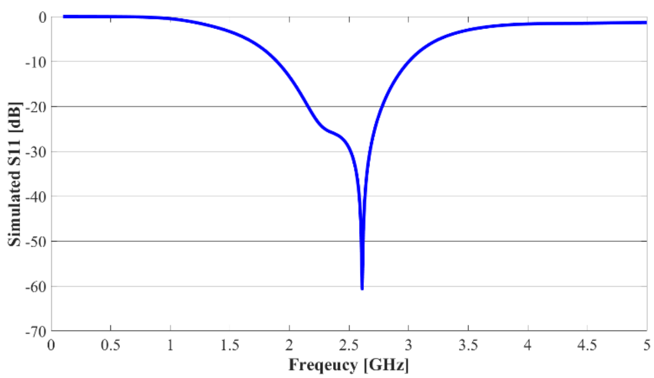

Fig. 2. S11 Parameter of CPW-Fed Antenna

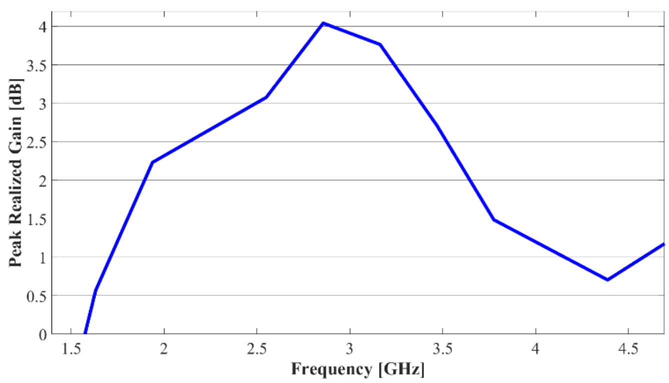

Fig. 3. Peak Realized Gain of CPW-Fed Antenna

Figs. 4 and 5 show the 3D gain plot of the antenna and 2D radiation patterns at 2.5 GHz, respectively. The gain plot in Fig. 4, shows a strong solid 3D pattern at the highest radiation frequency of 2.5 GHz. The radiation patterns, Fig. 5, are shown for x-z ($\phi = 0°$) and y-z ($\phi = 90°$) planes. As seen, cross-polarization fields are significantly lower than the co-polarization radiation fields. The difference is around 40 dB at the boresight.

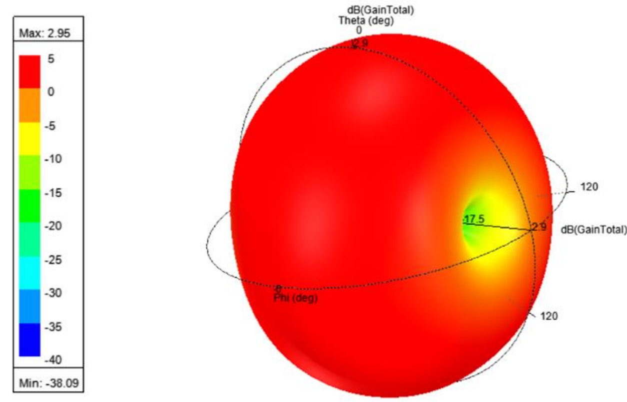

Fig. 4. 3D Gain Pattern for CPW-Fed Antenna

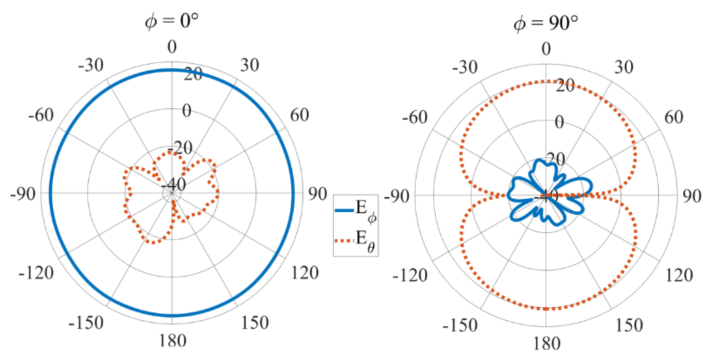

Fig. 5. Radiation Patterns at (a) Phi = 0° and (b) Phi = 90°

IV. CONCLUSION

This paper presents a wideband CPW-Fed patch antenna for harsh environments. The radiation patterns confirm a strong monopole behavior with low cross-polarization fields. Additionally, the range of the frequency band contains the possibility of WLAN and ISM band applications, which show the possible utility of the ZRC as a substrate candidate for high-temperature applications. A physical prototype will be constructed based on this design to confirm its performance.

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