This paper presents a high-performance dual-circularly polarized feed employing a dielectric-filled circular waveguide. Novel features are incorporated in the proposed feed, such as a dielectric rod radiator for high gain and good impedance matching; dual quarter-wave chokes for low axial ratio over wide angles and for low back radiation; an integrated septum polarizer; and two end-launch-type coaxial-to-waveguide transitions. The proposed feed shows excellent performance at 5.0 GHz to 5.2 GHz.

Keywords: Reflector antenna feed, dual-circular polarization, low axial ratio.
Fig. 1. Proposed dual-circularly polarized feed.

with an impedance-matching hollow region; three grooves for further impedance matching; dual chokes for low axial ratio over a wide angle and for low back-lobe radiation; a septum polarizer for dual polarization generation and separation; and two coaxial-to-waveguide transitions.

The septum polarizer acts both as a polarizer and as an orthomode transducer generating right and left circularly-polarized waves. Its operating principles are well known [7] and are not repeated in this paper.

The proposed feed is designed in the following steps. First, the feed is designed without the septum polarizer and coaxial transition. Second, the septum polarizer and coaxial transition are designed separately and then combined. Finally, the overall structure is constructed and optimized. The impedance-matching grooves and coaxial transition are adjusted for better impedance matching. The widely used Microwave Studio™ v. 2012 by CST has been employed in the design.

The circular waveguide is filled with low-loss polycarbonate material having dielectric constant of 2.76 and loss tangent of 0.0005 at 5 GHz to reduce the waveguide diameter. The dielectric rod radiator [8] is realized by extending the polycarbonate material filling the waveguide. A hollow cylinder is formed at the rod’s end for impedance matching. The gain and beamwidth of the feed are controlled by adjusting the diameter and length of the rod.

Three grooves on the dielectric rod inside the waveguide, together with the hollow region at the rod’s end, improve the impedance matching. Groove regions are filled with air. Groove dimensions and locations were iteratively optimized for good impedance matching at 5.0 GHz to 5.2 GHz. Figure 2 shows the impedance matching performances with and without the three grooves. The reflection coefficient is reduced from –11 dB to –21 dB at 5.1 GHz.

Dual chokes improve the axial ratio at wide angles and suppress the back lobe. The initial depths of the dual chokes are set to 0.25 \( \lambda_0 \) and 0.5 \( \lambda_0 \), and their optimum values are obtained by a parameter sweep. Figures 3 and 4 show the effects of the dielectric rod and dual chokes on the antenna performance. The dielectric rod increases the gain by about 3 dB. The dual chokes suppress the back radiation by about 9 dB and
significantly lower the axial ratio at angles beyond ±30°.

Feed components are separately designed and combined to form the final structure, which is then further optimized to account for interaction between components. Dimensions of the optimally designed feed are shown in Figure 5 and Table 1.

A septum polarizer with five steps is employed for the generation of a dual-circularly polarized wave. Step dimensions are determined by parameter sweeps for good impedance matching, high isolation, and low axial ratio. Figure 6 shows the performance of the designed septum polarizer. Over 5.0 GHz to 5.2 GHz, the reflection coefficient is less than –30 dB, the isolation between the two input semicircular waveguides is greater than 29 dB, and the axial ratio is less than 0.25 dB.

An end-launcher-type coaxial-to-circular waveguide transition [9] having a reflection coefficient less than –23 dB at 5.0 GHz to 5.2 GHz is designed to connect the feed to the receiver.
Figure 7 shows the fabricated feed and its components. The performance of the fabricated feed was measured and is shown in Figures 8–11. At 5.0 GHz to 5.2 GHz, the measured reflection coefficient is less than –21 dB, and the isolation between the RHCP and LHCP ports is greater than 20 dB, as shown in Fig. 8.

Figure 9 shows the measured co- and cross-polarized gain patterns in the plane normal to the septum surface. The antenna’s measured gain is 9.8 dBi, and the half beamwidth at the 10 dB taper level is 59.6°. The cross-polarization level is less than –19 dB over –60° ≤ θ ≤ +60°.

Figure 10 shows the measured axial ratio, which is 0.5 dB at θ = 0° and 1.8 dB at θ = ±60°. Figure 11 shows the phase center versus the frequency relative to the rod’s end. At 5.0 GHz to 5.2 GHz, the phase center varies from –27.5 mm to –28.0 mm. The fabricated feed’s performance agrees well with the simulation.

III. Conclusion

This paper presented a dual-circularly polarized feed employing a dielectric-filled circular waveguide. The proposed feed incorporated a circular-waveguide-fed dielectric rod antenna made of low-loss polycarbonate material, impedance-matching grooves, dual quarter-wave chokes, a septum polarizer, and two coaxial transitions. The proposed feed showed excellent characteristics, such as compactness, low axial ratio over wide angles, and low back radiation. The concept proposed in this paper can be applied to the design of high-performance feeds for prime-focus tracking reflector antennas with a wide range of F/D (front-to-back) ratios by properly adjusting the dielectric rod length.

References

3, June 2011, pp. 142–146.


Joo-Young Lim received his BS degree in computer software engineering from Korean Bible University, Seoul, Rep. of Korea, in 2013. Since 2013, he has been working toward his MS degree in radio and communications engineering at Chungbuk National University, Cheongju, Rep. of Korea. His research interests include waveguide structure design and antenna engineering.

Jargalsaikhan Nyamabayar received his BS and MS degrees in information measuring electronics and telecommunications from the School of Information and Communication Technology, Mongolian University of Science and Technology, Ulaanbaatar, Mongolia, in 2011 and 2013, respectively. Since 2013, he has been working toward his doctoral degree at the School of Electrical and Computer Engineering, Chungbuk National University, Cheongju, Rep. of Korea. His research interests include antenna engineering, active device design, and microwave engineering.

Je-Young Yun is currently working toward his BS degree in information and communications engineering at Chungbuk National University, Cheongju, Rep. of Korea. His research interests include antennas and microwave circuits.

Bierng-Chearl Ahn received his BS degree in electrical engineering from Seoul National University, Seoul, Rep. of Korea, in 1981, his MS degree in electrical engineering from KAIST, Daejeon, Rep. of Korea, in 1983, and his PhD degree in electrical engineering from the University of Mississippi, MS, USA, in 1992. From 1983 to 1986, he worked for the Goldstar Precision Company, Anyang, Rep. of Korea, as a research engineer, and from 1993 to 1994, he worked at the Agency for Defense Development, Daejeon, Rep. of Korea. Since 1995, he has been with Chungbuk National University, Cheongju, Rep. of Korea, where he is currently a professor at the School of Electrical and Computer Engineering. His research interests include applied electromagnetics and antennas.

Dong-Hyun Kim received his BS and MS degrees in radio communication engineering from Korea Maritime and Ocean University, Busan, Rep. of Korea, in 1997 and 1999, respectively. From 2000 to 2005, he served as a captain in the Republic of Korea Air Force. Since 2005, he has been with the Korea Aerospace Research Institute, Daejeon, Rep. of Korea, where he is currently a senior researcher at the Naro Space Center. His research interests include telemetry engineering and antennas.

Tae-Hyung Kim received his BS and MS degrees in electronics engineering from Kyungpook National University, Daegu, Rep. of Korea, in 1989 and 1991, respectively. He has worked at the Agency for Defense Development, Daejeon, Rep. of Korea, from 1991 to 1996 and at DACOM R&D Center, Daejeon, Rep. of Korea, from 1997 to 2002. In 2002, he joined the Korea Aerospace Research Institute, Daejeon, Rep. of Korea, where he is currently the head of the Launch Operations Department, Naro Space Center. His research interests include tracking systems and antennas.

Je-Young Yun is currently working toward his BS degree in information and communications engineering at Chungbuk National University, Cheongju, Rep. of Korea. His research interests include antennas and microwave circuits.

Jae-Hoon Bang received his BS and MS degrees in radio and communications engineering and his PhD degree in information and communications engineering from Chungbuk National University, Cheongju, Rep. of Korea, in 1997, 1999, and 2003, respectively. From 2003 to 2007, he worked as a research engineer at Kukdong Telecommunications Company, Nonsan, Rep. of Korea. He is currently working at the BK21 Chungbuk Information Technology Center, Chungbuk University, as a visiting professor. His research interests include numerical techniques in electromagnetics, military radar systems, and antenna engineering.

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