Borrador

Acoplador híbrido en cuadratura implementado en guía de ondas Gap de medio modo

Miguel Ferrando-Rocher[(1)(2)]
(1) Microwave and Applied Computational Electromagnetics group (GMECA) , University of Alicante (Spain)
(2) Universitat Politècnica de València, Spain; e-mail: miguel.ferrando.@upv.es

La conmutación de haces es una función muy demandada en la banda de ondas milimétricas. El grial sigue siendo encontrar una solución totalmente electrónica capaz de conmutar de forma independiente la amplitud y la fase de cada elemento radiante. Mientras tanto, se exploran soluciones intermedias como son las redes de conformación de haz. Entre algunos ejemplos destacados se pueden nombrar la matriz de Butler o la matriz de Blass, que han sido ampliamente estudiadas y desarrolladas. Estas redes están típicamente compuestas de acopladores híbridos. En este contexto, se presenta un acoplador híbrido de tipo branch-line como elemento básico de una futura novedosa red de conformación de haz que mitigue algunos de los problemas que presentan las redes anteriormente descritas.

Por tanto, esta comunicación que se presentará en mayor detalle y de manera completa en el congreso EuCAP 2023, consta de un acoplador de una sola capa, completamente metálico, de bajas pérdidas e implementado en una guía de onda gap de medio modo. La banda de trabajo del acoplador híbrido en cuadratura oscila entre 29 GHz a 31 GHz. La potencia de salida simulada de -3 dB se alcanza tanto para el puerto directo como para el puerto acoplado. Se obtiene un nivel de -20 dB en el puerto desacoplado. Las dimensiones totales del dispositivo son 10 mm $\times$ 10 mm $\times$ 14 mm. Este diseño, aunque sencillo, es un bloque útil que podrá integrarse posteriormente en estructuras más complejas, como redes de conformación de haz para agrupaciones de antenas en la banda de ondas milimétricas. .

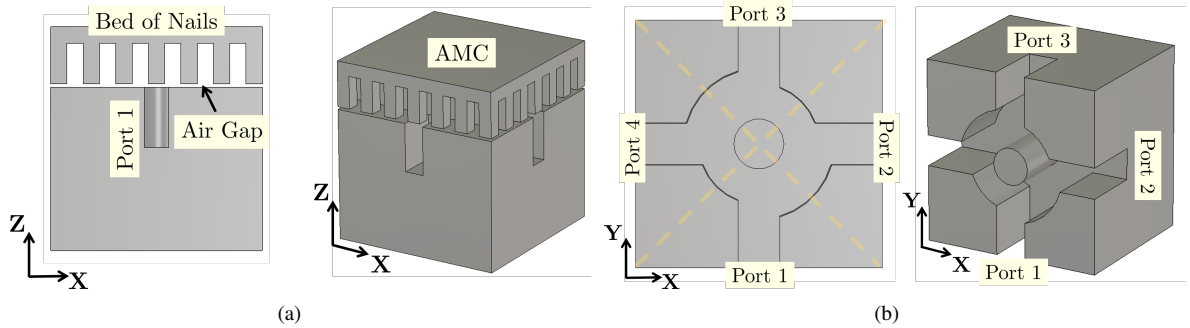

Figura 1. (a) Vistas frontal y lateral del híbrído usando HM-GGW (Half-Mode Groove Gap Waveguide). (b) Vista superior y perspectiva del híbrido sin la cama de pines superior, para una mejor visualización.

References

[1] A. Valero-Nogueira, J. I. Herranz-Herruzo, M. Ferrando-Rocher, R. Lenormand, A. Hirsch, and J.-L. Almeida, "Switchable rhcp/lhcp slotted waveguide array antenna for satcom on-the-move applications in ka-band," in *The 8th European Conference on Antennas and Propagation (EuCAP 2014)*. IEEE, 2014, pp. 2047–2051.

[2] J. I. Herranz-Herruzo, A. Valero-Nogueira, M. Ferrando-Rocher, B. Bernardo-Clemente, R. Lenormand, A. Hirsch, J.-L. Almeida, M. Arnaud, and L. Barthe, "Low cost switchable rhcp/lhcp antenna for sotm applications in ka-band," in *2015 9th European Conference on Antennas and Propagation (EuCAP)*. IEEE, 2015, pp. 1–4.

[3] J. Herranz-Herruzo, M. Ferrando-Rocher, A. Valero-Nogueira, R. Lenormand, A. Hirsch, J. Almeida, M. Arnaud, and L. Barthe, "Locomo satcom terminal: A switchable rhcp/lhcp array antenna for on-the-move applications in ka-band," in *2015 IEEE International Symposium on Antennas and Propagation & USNC/URSI National Radio Science Meeting*. IEEE, 2015, pp. 210–211.

[4] A. Berenguer, V. Fusco, M. Ferrando-Rocher, and V. E. Boria, "A fast analysis method for the groove gap waveguide using transmission line theory," in *2016 10th European Conference on Antennas and Propagation (EuCAP)*. IEEE, 2016, pp. 1–5.

[5] M. Ferrando-Rocher, A. Valero-Nogueira, J. I. Herranz-Herruzo, A. Berenguer, and B. Bernardo-Clemente, "Groove gap waveguides: A contactless solution for multilayer slotted-waveguide array antenna assembly," in *2016 10th European Conference on Antennas and Propagation (EuCAP)*. IEEE, 2016, pp. 1–4.

[6] M. Ferrando-Rocher, J. I. Herranz-Herruzo, A. Valero-Nogueira, and V. M. Rodrigo, "Circularly polarized slotted waveguide array with improved axial ratio performance," *IEEE Transactions on Antennas and Propagation*, vol. 64, no. 9, pp. 4144–4148, 2016.

[7] M. Ferrando-Rocher, A. Valero-Nogueira, J. I. Herranz-Herruzo, and A. Berenguer, "V-band single-layer slot array fed by ridge gap waveguide," in *2016 IEEE International Symposium on Antennas and Propagation (APSURSI)*. IEEE, 2016, pp. 389–390.

[8] A. Berenguer, M. Baquero-Escudero, M. Ferrando-Rocher, B. Bernardo-Clemente, and V. E. Boria, "An effective post-manufactured tuning method for gap waveguide components," in *2016 IEEE International Symposium on Antennas and Propagation (APSURSI)*. IEEE, 2016, pp. 493–494.

[9] T. Makdissy, R. Gillard, E. Fourn, M. Ferrando-Rocher, E. Girard, H. Legay, and L. Le Coq, "'phoenix'reflectarray unit cell with reduced size and inductive loading," *IET Microwaves, Antennas & Propagation*, vol. 10, no. 12, pp. 1363–1370, 2016.

[10] M. Ferrando-Rocher, A. Valero-Nogueira, and J. I. Herranz-Herruzo, "New feeding network topologies for high-gain single-layer slot array antennas using gap waveguide concept," in *2017 11th European Conference on Antennas and Propagation (EUCAP)*. IEEE, 2017, pp. 1654–1657.

[11] M. Ferrando-Rocher, A. Zaman, J. Yang, and A. Valero-Nogueira, "A dual-polarized slotted-waveguide antenna based on gap waveguide technology," in *2017 11th European Conference on Antennas and Propagation (EUCAP)*. IEEE, 2017, pp. 3726–3727.

[12] J. I. Herranz-Herruzo, A. Valero-Nogueira, M. Ferrando-Rocher, B. Bernardo, A. Vila, and R. Lenormand, "Low-cost ka-band switchable rhcp/lhcp antenna array for mobile satcom terminal," *IEEE Transactions on Antennas and Propagation*, vol. 66, no. 5, pp. 2661–2666, 2018.

[13] M. Ferrando-Rocher, J. Herranz-Herruzo, A. Valero-Nogueira, and B. Bernardo-Clemente, "Satcom on-the-move antenna with mechanically switchable circular polarization," 2017.

[14] M. Ferrando-Rocher, J. I. Herranz-Herruzo, A. Valero-Nogueira, and B. Bernardo-Clemente, "Performance assessment of gap-waveguide array antennas: Cnc milling versus three-dimensional printing," *IEEE Antennas and Wireless Propagation Letters*, vol. 17, no. 11, pp. 2056–2060, 2018.

[15] M. Ferrando-Rocher, J. I. Herranz-Herruzo, A. Valero-Nogueira, and A. Vila-Jiménez, "Single-layer circularly-polarized *ka*-band antenna using gap waveguide technology," *IEEE Transactions on Antennas and Propagation*, vol. 66, no. 8, pp. 3837–3845, 2018.

[16] E. Rajo-Iglesias, M. Ferrando-Rocher, and A. U. Zaman, "Gap waveguide technology for millimeter-wave antenna systems," *IEEE Communications Magazine*, vol. 56, no. 7, pp. 14–20, 2018.

[17] D. Sánchez-Escuderos, M. Ferrando-Rocher, J. I. Herranz, H. C. Moy-li, and A. Valero-Nogueira, "Dual-polarized frequency selective surface for sotm applications," 2018.

[18] M. Ferrando-Rocher, D. Sánchez-Escnderos, J. I. Herranz-Herruzo, and A. Valero-Nogueira, "Design of broadband gap waveguide transitions for millimeter-wave antenna arrays," in *2018 48th European Microwave Conference (EuMC)*. IEEE, 2018, pp. 1521–1524.

[19] D. Sánchez-Escuderos, M. Ferrando-Rocher, J. I. Herranz, and A. Valero-Nogueira, "Linear to circular fss transformer for dual-polarized applications," in *2018 IEEE International Symposium on Antennas and Propagation & USNC/URSI National Radio Science Meeting*. IEEE, 2018, pp. 2053–2054.

[20] M. Ferrando-Rocher, J. I. Herranz-Herruzo, A. Valero-Nogueira, and M. Baquero-Escudero, "Flatness enhancement of gap waveguide slot arrays using a ribbed-grid plate," in *2018 IEEE International Symposium on Antennas and Propagation & USNC/URSI National Radio Science Meeting*. IEEE, 2018, pp. 419–420.

[21] M. Baquero-Escudero, A. Valero-Nogueira, M. Ferrando-Rocher, B. Bernardo-Clemente, and V. E. Boria-Esbert, "Compact combline filter embedded in a bed of nails," *IEEE Transactions on Microwave Theory and Techniques*, vol. 67, no. 4, pp. 1461–1471, 2019.

[22] M. Ferrando-Rocher, A. Valero-Nogueira, J. I. Herranz-Herruzo, and J. Teniente, "60 ghz single-layer slot-array antenna fed by groove gap waveguide," *IEEE Antennas and Wireless Propagation Letters*, vol. 18, no. 5, pp. 846–850, 2019.

[23] M. Ferrando-Rocher, J. I. Herranz-Herruzo, A. Valero-Nogueira, B. Bernardo-Clemente, A. U. Zaman, and J. Yang, "8×8 ka-band dual-polarized array antenna based on gap waveguide technology," *IEEE Transactions on Antennas and Propagation*, vol. 67, no. 7, pp. 4579–4588, 2019.

[24] M. Ferrando-Rocher, J. I. Herranz-Herruzo, A. Valero-Nogueira, and B. Bernardo-Clemente, "Full-metal k-ka dual-band shared-aperture array antenna fed by combined ridge-groove gap waveguide," *IEEE Antennas and Wireless Propagation Letters*, vol. 18, no. 7, pp. 1463–1467, 2019.

[25] ——, "Compact k/ka dual-band antenna on gap waveguide technology," in *2019 13th European Conference on Antennas and Propagation (EuCAP)*. IEEE, 2019, pp. 1–4.

[26] D. Sánchez-Escuderos, M. Ferrando-Rocher, J. I. Herranz-Herruzo, and A. Valero-Nogueira, "Single-layer dual-band slot-array antenna in gap waveguide technology," in *2019 13th European Conference on Antennas and Propagation (EuCAP)*. IEEE, 2019, pp. 1–4.

[27] M. Ferrando-Rocher, A. Valero-Nogueira, and J. I. Herranz-Herruzo, "K/ka dual-band dual-polarized gap waveguide array antenna," in *2019 IEEE International Symposium on Antennas and Propagation and USNC-URSI Radio Science Meeting*. IEEE, 2019, pp. 663–664.

[28] D. Sánchez-Escuderos, M. Ferrando-Rocher, J. I. Herranz-Herruzo, and A. Valero-Nogueira, "Grating lobes reduction using a multilayer frequency selective surface on a dual-polarized aperture array antenna in ka-band," *IEEE Access*, vol. 8, pp. 104 977–104 984, 2020.

[29] M. Ferrando-Rocher, J. I. Herranz-Herruzo, A. Valero-Nogueira, and B. Bernardo-Clemente, "Dual circularly polarized aperture array antenna in gap waveguide for high-efficiency ka-band satellite communications," *IEEE Open Journal of Antennas and Propagation*, vol. 1, pp. 283–289, 2020.

[30] M. Ferrando-Rocher, J. I. Herranz-Herruzo, D. Sánchez-Escuderos, and A. Valero-Nogueira, "A novel circularly-polarized t-shaped slot array antenna in ka-band," in *2020 14th European Conference on Antennas and Propagation (EuCAP)*. IEEE, 2020, pp. 1–3.

[31] D. Sánchez-Escuderos, J. I. Herranz-Herruzo, M. Ferrando-Rocher, and A. Valero-Nogueira, "Mechanical phase shifter in gap-waveguide technology," in *2020 14th European Conference on Antennas and Propagation (EuCAP)*. IEEE, 2020, pp. 1–5.

[32] M. Ferrando-Rocher, "Gap waveguide array antennas and corporate-feed networks for mm-wave band applications," Ph.D. dissertation, Universitat Politècnica de València, 2018.

[33] D. Sánchez-Escuderos, J. I. Herranz-Herruzo, M. Ferrando-Rocher, and A. Valero-Nogueira, "True-time-delay mechanical phase shifter in gap waveguide technology for slotted waveguide arrays in ka-band," *IEEE Transactions on Antennas and Propagation*, vol. 69, no. 5, pp. 2727–2740, 2020.

[34] M. Ferrando-Rocher, J. I. Herranz-Herruzo, A. Valero-Nogueira, and M. Baquero-Escudero, "Dual-band single-layer slot array antenna fed by k/ka-band dual-mode resonators in gap waveguide technology," *IEEE Antennas and Wireless Propagation Letters*, vol. 20, no. 3, pp. 416–420, 2021.

[35] M. Ferrando-Rocher, J. I. Herranz-Herruzo, A. Valero-Nogueira, and B. Bernardo-Clemente, "Selective laser sintering manufacturing as a low cost alternative for flat-panel antennas in millimeter-wave bands," *IEEE Access*, vol. 9, pp. 45 721–45 729, 2021.

[36] M. Ferrando-Rocher, J. I. Herranz-Herruzo, and A. Valero-Nogueira, "Wideband coffee-bean shaped radiating element for circularly-polarized waveguide slot arrays," in *2021 15th European Conference on Antennas and Propagation (EuCAP)*, 2021.

[37] A. Morales-Hernández, M. Ferrando-Rocher, M. Á. Sánchez-Soriano, S. Marini, and V. E. Boria Esbert, "Design strategy and considerations to improve corona discharge breakdown in groove gap waveguides," in *2021 15th European Conference on Antennas and Propagation (EuCAP)*. IEEE, 2021.

[38] M. Ferrando-Rocher, B. Mayor, S. Marini, J. I. Herranz-Herruzo, and A. Valero-Nogueira, "A ka-band compact single-layer gap waveguide monopulse slot array antenna," in *XXXIV General Assembly and Scientific Symposium (GASS) of the International Union of Radio Science*. IEEE, 2021.

[39] J. I. Herranz-Herruzo, M. Ferrando-Rocher, A. Valero-Nogueira, and B. Bernardo-Clemente, "Novel asymmetric t-shaped radiating element for circularly-polarized waveguide slot arrays," *IEEE Transactions on Antennas and Propagation*, vol. 69, no. 11, pp. 7452–7461, 2021.

[40] M. Ferrando-Rocher, J. I. Herranz-Herruzo, A. Valero-Nogueira, and B. Bernardo-Clemente, "Switchable t-slot for dual-circularly-polarized slot-array antennas in ka-band," *IEEE Antennas and Wireless Propagation Letters*, vol. 20, no. 10, pp. 1953–1957, 2021.

[41] M. Ferrando-Rocher, J. I. Herranz-Herruzo, A. Valero-Nogueira, and M. Baquero-Escudero, "Half-mode waveguide based on gap waveguide technology for rapid prototyping," *IEEE Microwave and Wireless Components Letters*, vol. 32, no. 2, pp. 117–120, 2021.

[42] J. I. Herranz-Herruzo, A. Valero-Nogueira, M. Ferrando-Rocher, and B. Bernardo-Clemente, "High-efficiency ka-band circularly polarized radial-line slot array antenna on a bed of nails," *IEEE Transactions on Antennas and Propagation*, vol. 70, no. 5, pp. 3343–3353, 2021.

[43] A. Morales-Hernández, M. Á. Sánchez-Soriano, M. Ferrando-Rocher, S. Marini, M. T. Calduch, and V. E. Boria, "Peak power handling capability in groove gap waveguide filters based on horizontally polarized resonators and enhancement solutions," *IEEE Microwave and Wireless Components Letters*, vol. 32, no. 7, pp. 859–862, 2022.

[44] C. Vazquez-Sogorb, M. Ferrando-Rocher, S. Marini, and J. I. Herranz-Herruzo, "A gap waveguide-based 2×2 circularly-polarized monopulse antenna array," in *2022 16th European Conference on Antennas and Propagation (EuCAP)*. IEEE, 2022, pp. 1–3.

[45] M. Ferrando-Rocher, J. I. Herranz-Herruzo, A. Valero-Nogueira, and B. Bernardo-Clemente, "Single-layer sequential rotation network in gap waveguide for a wideband low-profile circularly polarized array antenna," *IEEE Access*, vol. 10, pp. 62 157–62 163, 2022.

[46] M. Ferrando-Rocher, J. I. Herranz-Herruzo, A. Valero-Nogueira, and M. Baquero-Escudero, "A half-mode groove gap waveguide for single-layer antennas in the millimeter-wave band," *IEEE Antennas and Wireless Propagation Letters*, vol. 21, no. 12, pp. 2402–2406, 2022.

[47] J. I. Herranz-Herruzo, M. Ferrando-Rocher, and A. Valero-Nogueira, "Multimode coupled slots for wideband circularly-polarized mm-wave all-metal antennas," in *2022 IEEE International Symposium on Antennas and Propagation and USNC-URSI Radio Science Meeting (AP-S/URSI)*. IEEE, 2022, pp. 399–400.

[48] J. I. Herranz-Herruzo, M. Ferrando-Rocher, A. Valero-Nogueira, and B. Bernardo-Clemente, "Wideband circularly-polarized mm-wave array antenna using h-shaped low-axial-ratio apertures," *IEEE Transactions on Antennas and Propagation*, 2023.