DUAL-BAND REDUCED-SIZE CIRCULARLY-POLARIZED CO-PLANAR PRINTED-CIRCUIT ANTENNA ELEMNT

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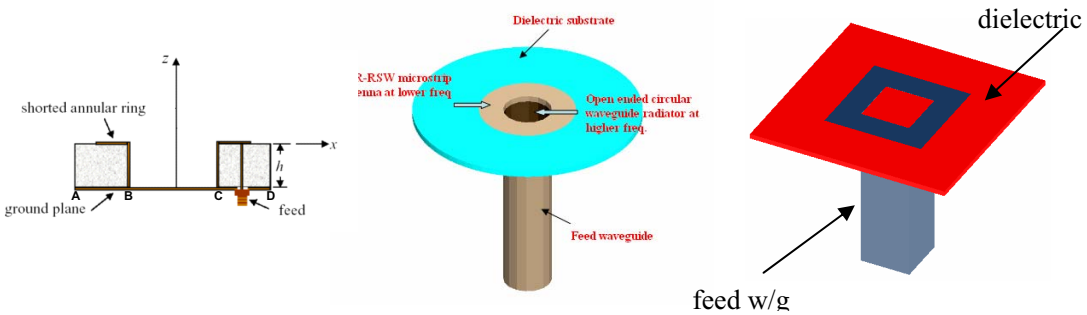
Abstract: A concept for a dual-band antenna element that combines a shorted annular ring (SAR) with a printed circuit perturbed slot/patch is presented. The two elements are co-planar and use the same overall aperture size as the SAR element. The element outer diameter is reduced by as much as 42% by using a capacitive loading that employs a high dielectric constant ring. The printed slot/patch occupies the inner circle of the SAR element and is designed to produce a circular polarization at the higher frequency with a single point feeding. The SAR operates at the lower frequency with sequential-phase four-point or two-point feeding for circular polarization. Both the SAR element and the printed circuit slot/patch can also independently operate at linear polarization or a combination of linear and circular polarizations. The dual-band feature is desirable in several wireless and satellite communications applications.

1. INTRODUCTION

A number of techniques have been reported for dual band operation in printed circuit antenna elements [1]. Using a rectangular patch would produce two resonant frequencies at two orthogonal polarizations that correspond to the two orthogonal dimensions of the patch. Reusing the radiating aperture for two different radiators would also produce dual band operation. Other methods include external loading of the patch to achieve the dual band. In a recent development, the central region of the shorted annular ring (SAR) printed circuit element [2] was used to house a waveguide radiator that operates at a higher frequency band [3], [4]. The SAR and hybrid element configurations are shown in Figure 1. The SAR and waveguide radiators have independent feeding and independent polarization mechanisms. The size of the outer ring of the SAR radiator is determined by the lower frequency of the hybrid structure and thus exceeds a half wavelength at the higher frequency of the waveguide radiator. This limits the use of the hybrid element in an array environment at the higher frequency band. Capacitive loading of the SAR element and the use of higher dielectric constant in part of the capacitive loading structure can reduce the outer dimensions of the element by as much as 42%, which allows closer spacing between the elements in array environment [5].



(a) Basic SAR (b) Circular Dual-Band Hybrid (c) Square Dual-Band Hybrid

Figure 1 Basic SAR Element and Dual-Band Hybrid Elements [4]

The concept of combining the dual-band hybrid element and the capacitive loading for the reduction of the SAR size is introduced in this paper. The reduced-size aperture allows the element to be used in array environments at both bands. Also introduced is a concept for a different type of dual-band arrangement where the central region of the SAR element is occupied by an efficient printed circuit element with inherent single-feeding circular polarization features. The combination is a low-profile small-aperture dual-band and independent polarization element that can be used in array environments at both bands.

2. DUAL-BAND HYBRID ELEMENT WITH CAPACITIVE LOADING

The capacitive loading of the SAR element for the purpose of reducing its aperture size is reported in [5]. A loading ring is added at the outer ring. The ring/cylinder is terminated in a capacitive patch that uses a material with a high dielectric constant. The configuration is shown in Figure 2. The capacitive loading reduced the outer diameter of the element to 0.2185 λ as compared to the unloaded diameter of 0.376 λ, a reduction of 42%.

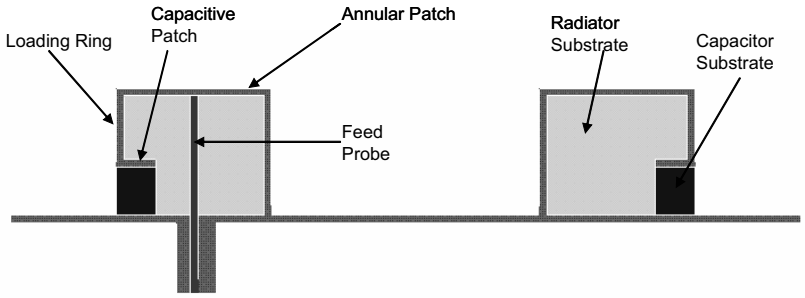
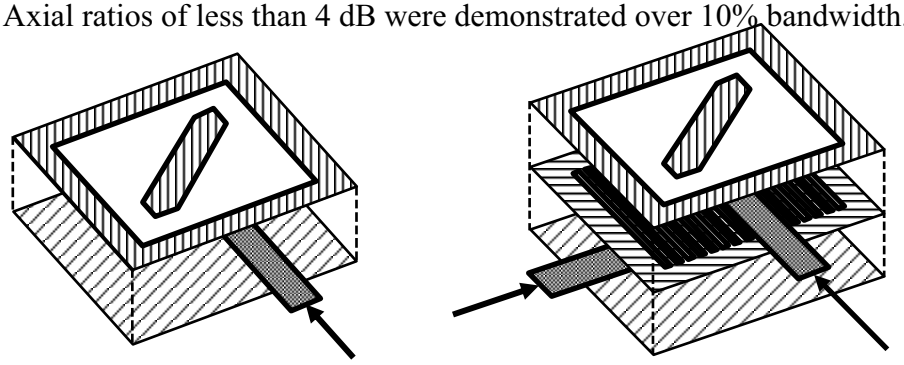


Figure 2 Capacitive Edge-Loading of SAR Antenna Element [5]

A dual band element shown in Figure 1(b) can be designed such that the SAR element operates at the lower frequency of 3.0 GHz and its circular waveguide insert operates at 6.3 GHz using inner and outer radii of 13.9 and 27.8 mm, respectively. The outer diameter is 1.17 λ at 6.3 GHz which constitutes a significant grating lobe problem if used in an array environment. If capacitive loading is used, the outer radius can be reduced to 16.1 mm, resulting in a diameter of 0.677 λ at 6.3 GHz. The element spacing can be around 0.75 λ, which allows for around 45-degree grating-lobe-free scanning range.

3. DUAL-BAND SAR/PERTURBED SLOT ELEMENT

Circular polarization can be produced by perturbing the edges of printed circuit patches and slots that result in single point feeding of the element [6], versus two orthogonal feedings at a 90-degree phase difference. Figure 3 shows single and dual circularly polarized elements using this perturbation method. The feed lines are implemented in striplines in order to limit the losses. Axial ratios of less than 4 dB were demonstrated over 10% bandwidth.



(a) Single Circular Polarization (b) Dual Circular Polarizations

Figure 3 Single-Feeding Circularly-Polarized Element Using a Perturbed Slot

The perturbation slot element can be used in the center portion of the SAR element and will resonate at the higher frequency. The result is a dual-band element with co-planar radiators with simple circular polarization feeding. The element is shown in Figure 4 in the square configuration. Similar arrangement can be configured for the circular SAR element. While the perturbed slot radiator produces the circular polarization with a single point feeding, the SAR radiator is fed with a four-point or two-point sequential-phase feeding to produce circular polarization. The polarizations of the two radiators are independent of each other and can be linear or circular.

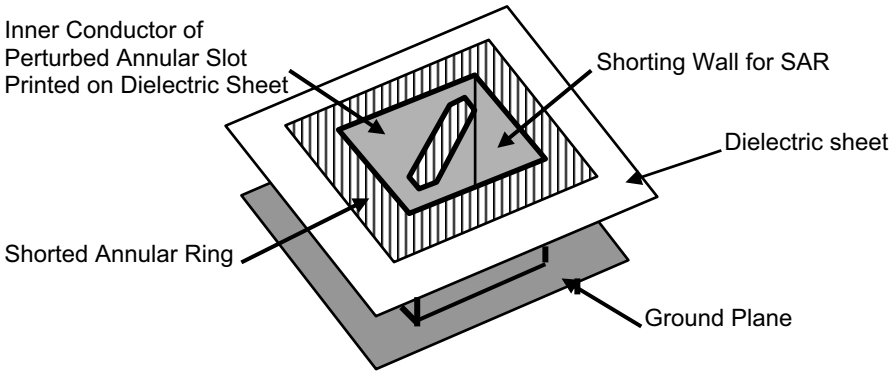


Figure 4 Dual-Band SAR/Perturbed Slot Element

Similar to the hybrid element, the outer dimensions of the SAR/perturbed slot element can be reduced by using capacitive edge loading with high dielectric constant material at the bottom of the loading ring. This will allow using the element in array environment at the higher frequency. The feed network for the array is easily built into the multilayer structure, thus ensuring a low profile for the complete dual band antenna array.

4. CONCLUSION

A concept for a dual-band antenna element shows a promise for co-planar radiators with small aperture size to ensure operation at the higher frequency band in array environments. The feeding of the printed circuit radiators is embedded in the multilayer structure with circular polarizations achieved using single point feeding for the inner radiator and four-point or two-point sequential-phase feeding for the outer SAR radiator. The outer radiator is capacitively loaded with a high dielectric-constant ring to reduce the overall size of the element.

REFERENCES

[1] S. Maci and G. B. Gentili, "Dual-Frequency Patch Antennas," *IEEE Antennas and Propagation Magazine*, vol. 39, no. 6, pp. 13 - 20, December 1997.

[2] D.R. Jackson, J.T. Williams, A.K. Bhattacharyya, R.L. Smith, S.J. Buchheit and S.A. Long, "Microstrip Patch Designs That Do Not Excite Surface Waves," *IEEE Transactions on Antennas and Propagation*, vol. 41, no. 8, pp. 1026 - 1037, August 1993.

[3] C.B. Ravipati and A.I. Zaghloul, "A Hybrid Antenna Element for Dual-Band Applications, IEEE Antennas and Propagation Society International Symposium Digest, Monterey, CA, vol. 4, pp. 3412-3415, June 2004.

[4] A.I. Zaghloul, C.B. Ravipati and M.T. Kawser, "Modeling and Analysis of a Dual-Band Dual-Polarization Radiator Using FEKO," *The Applied Computational Electromagnetics (ACES) Journal*, Vol. 22, No. 1, March 2007.

[5] W.M. Dorsey and A.I. Zaghloul, "Size Reduction and Bandwidth Enhancement of Shorted Annular Ring (SAR) Antenna," IEEE International Symposium on Antennas and Propagation, Honolulu, Hawaii, June 2007.

[6] R.M. Sorbello and A.I. Zaghloul, "Wideband, High-Efficiency, Circularly Polarized Slot Elements," IEEE Antennas and Propagation Symposium, San Jose, CA, June 26-29, 1989.