Sleeve Monopole Antenna with Integrated Filter for Base Station Applications

Joshua W. Shehan[1,2]
[1]Amphenol Antenna Solutions
Conover, NC, USA
jshehan@amphenol-antennas.com

Ryan S. Adams[2]
[2]Department of Electrical and Computer Engineering
University of North Carolina at Charlotte
Charlotte, NC, USA

***Abstract*—The sleeve monopole antenna with an integrated broadband filter is presented for base station applications. The antenna is designed to radiate from 698-960 MHz (low band) and provide band rejection from 1695-2690 MHz (high band). The antenna exhibits return loss better than -15 dB in the low band. The filter exhibits excellent rejection where the worst-case return loss is approximately -0.3 dB in the high band. The filter also reduces peak gain by as much as 50 dBi in the high band.**

I. Introduction

A major focus for modern mobile communications systems is improving network coverage and capacity in densely populated environments [1]. A practical base station antenna approach involves the use of broadband or multi-band antennas with omnidirectional azimuth radiation patterns for 360° coverage [2], [3]. Modern base station antennas typically cover frequencies from 698-960 MHz (low band) and 1695-2690 MHz (high band) where separate antenna elements or arrays may be used to cover individual bands or portions of each band [4]. The use of separate elements has key advantages, but there remains a potential for inter-band interference due to mutual coupling between the elements. Mitigation may require filtering at the element level or in the RF feed network [5].

This paper presents the sleeve monopole antenna with an integrated filter (patent pending) designed to radiate from 698-960 MHz and provide band rejection from 1695-2690 MHz. The sleeve monopole is an attractive candidate for omnidirectional base station antennas, and the sleeve presents a convenient location for the addition of filtering. Integrating the filter into the sleeve provides a compact solution for multi-band systems where inter-band coupling is minimized.

II. Sleeve Monopole Antenna with Integrated Filter

The proposed antenna is illustrated in Fig. 1 where the main radiator, sleeve, and base are made of copper. The main radiator includes a plate at the top that offers additional impedance matching and some height reduction. The antenna is fed with a 50-Ω coaxial cable where the outer shield of the cable is soldered to the antenna base, and the center conductor is soldered to the main radiator. The space between the main radiator and the base is fixed with 0.762 mm of Arlon AD255C (ϵ_r=2.55, tanδ=0.0014). All wall and plate thicknesses are set to 1.27 mm.

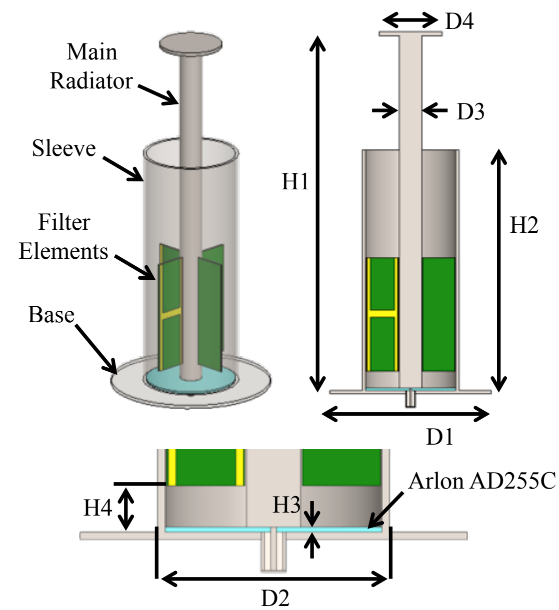

Fig. 1: Sleeve monopole antenna with four integrated filter elements. Each filter element contains an "H"-shaped metallization etched on one side of Arlon 25FR PCB material.

The antenna includes four identical filter elements that are based on the capacitively loaded strip (CLS) [6]. Each filter element is composed of an "H"-shaped metallization etched on one side of 0.762 mm thick Arlon 25FR (ϵ_r=3.58, tanδ=0.0035) as shown in Fig. 2. In this case, the elements are found to provide a broad stopband from 1695-2690 MHz with proper selection of the design parameters in Fig. 2. The filter elements are positioned centrally between the sleeve and the main radiator. The metallization of the filter and the metal components of the antenna do not touch, but their separation (S1+S2) should be kept to a minimum to maintain broadband filter performance. The distance H4 in Fig. 1 also plays a role in the filter response and can be controlled with a machined low dielectric foam insert.

III. Numerical Results

The return loss for the sleeve monopole with integrated filter is investigated and compared against that of a sleeve monopole

978-1-5090-4412-2/17/$31.00

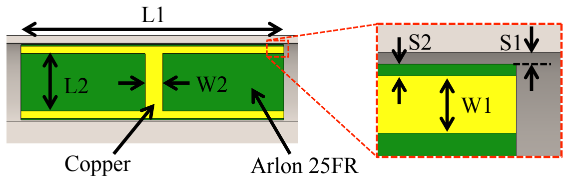

Fig. 2: Filter element for sleeve monopole antenna. The design parameters are L1 = 44.83 mm, L2 = 9.78 mm, W1 = 1.27 mm, W2 = 2.98 mm, and S1 = S2 = 0.254 mm.

without filtering. The results are plotted in Fig. 3. The two antennas are optimized for return loss in the low band, and their dimensions are compared in Table I. In both cases, the antennas achieve an input return loss better than -15 dB in the low band. The benefit of the filter is clearly observed in the high band where the antenna without the filter exhibits a return loss lower than -30 dB near 2.5 GHz. At this frequency, the monopole could easily couple to neighboring antennas causing interference. The addition of the filter completely eliminates the null in return loss at 2.5 GHz and exhibits a worst-case return loss of approximately -0.3 dB in the high band.

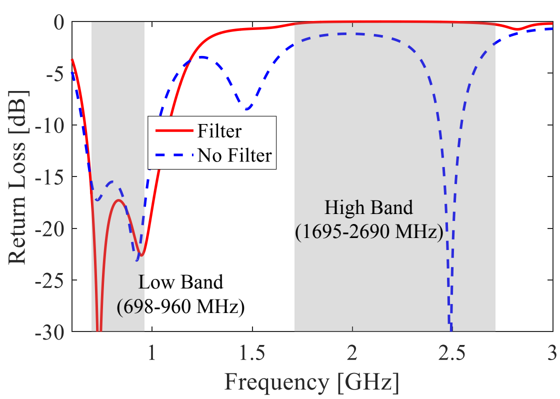

Fig. 3: Return loss for the sleeve monopole with filter (solid) and without filter (dashed).

TABLE I: Dimensions (mm) for antenna with filter and without filter

	D1	D2	D3	D4	H1	H2	H3	H4
Filter	63.5	38.1	8.89	24.89	143	95.25	0.762	7.62
No Filter	63.5	30.73	8.13	21.59	143	85.09	0.762	N/A

To further demonstrate the filter performance, the antenna patterns are shown in Fig. 4. The elevation (E-plane) pattern at ϕ=0° for both antennas at 825 MHz is shown in Fig. 4a, and the elevation pattern for both antennas at 2.5 GHz is shown in Fig. 4b. The pattern performance is marginally different between the two antennas at 825 MHz as expected, but the antenna with filtering shows a gain reduction of more than 20 dBi at 2.5 GHz. The filter achieves gain reductions between approximately 8-50 dBi in the high band minimizing the chance for inter-band interference. These results are plotted

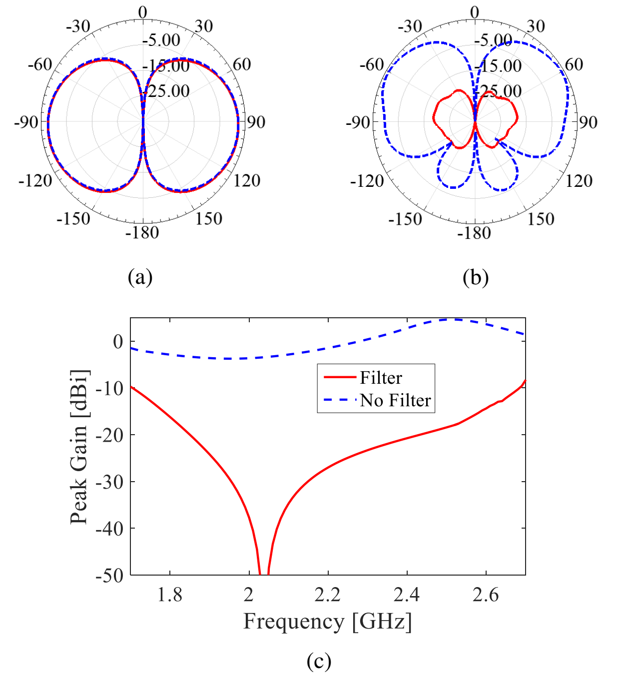

Fig. 4: Elevation patterns for antenna with filtering (solid) and without filtering (dashed) at 825 MHz (a) and at 2.5 GHz (b) along with peak gain in the high band (c).

in Fig. 4c. Note that the monopole exhibits omnidirectional radiation patterns in azimuth (H-plane) with and without the filter.

IV. Conclusion

This paper presents the sleeve monopole antenna with integrated filter for base station applications. The antenna exhibits excellent impedance matching with return loss better than -15 dB in the low band (698-960 MHz). The filter exhibits good rejection where the worst-case return loss is -0.3 dB in the high band (1695-2690 MHz). The antenna is ideal for omnidirectional multi-band base station applications where inter-band coupling is minimized.

References

[1] T. Nakamura, S. Nagata, A. Benjebbour, Y. Kishiyama, T. Hai, S. Xiaodong, Y. Ning, and L. Nan, "Trends in small cell enhancements in lte advanced," *IEEE Communications Magazine*, vol. 51, no. 2, pp. 98–105, February 2013.

[2] X. Quan and R. Li, "A broadband dual-polarized omnidirectional antenna for base stations," *IEEE Transactions on Antennas and Propagation*, vol. 61, no. 2, pp. 943–947, Feb 2013.

[3] P. Huang, Q. Guo, Z.-Y. Zhang, Y. Li, and G. Fu, "Design of a wideband sleeve antenna with symmetrical ridges," *Progress In Electromagnetics Research Letters*, vol. 55, pp. 137–143, 2015.

[4] Y. He, Z. Pan, X. Cheng, Y. He, J. Qiao, and M. M. Tentzeris, "A novel dual-band, dual-polarized, miniaturized and low-profile base station antenna," *IEEE Transactions on Antennas and Propagation*, vol. 63, no. 12, pp. 5399–5408, Dec 2015.

[5] Y. Zhang, X. Y. Zhang, L. H. Ye, and Y. M. Pan, "Dual-band base station array using filtering antenna elements for mutual coupling suppression," *IEEE Transactions on Antennas and Propagation*, vol. 64, no. 8, pp. 3423–3430, Aug 2016.

[6] R. W. Ziolkowski, "Design, fabrication, and testing of double negative metamaterials," *IEEE Transactions on Antennas and Propagation*, vol. 51, no. 7, pp. 1516–1529, July 2003.