A Wideband and Miniaturized Metal Rim Antenna with A New Material for Smartphone Applications

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***Abstract*—A new wideband and miniaturized metal rim antenna is developed based on a frequency-variant material for smartphone applications. The proposed antenna has a small clearance of 2 mm and uses a simple feeding method to cover the lower-frequency band (698-960 MHz) without impedance matching networks. This compact antenna, like a small module, can be placed at the top side of the substrate without extending to the long side which will reduce the user's hand effect significantly. Three cases with/without the new material are investigated and compared to demonstrate that the proposed antenna based on the new material has a wideband and is an excellent candidate for modern smartphone applications.**

***Index Terms*—Antennas, metal rim antenna, new materials, wideband smartphone antennas.**

I. Introduction

Recently, metal rim antenna with a small clearance for smartphone applications has become a research subject of huge interest, due to its excellent mechanical strength, aesthetic appearance, and high screen ratio. Researchers are making an effort to design a suitable metal rim antenna with small clearance and acceptable antenna performances. In [1], multiple resonant modes with a clearance of about 8 mm are adopted to cover 0.824 GHz to 0.96 GHz at the lower band. Another compact antenna with a clearance of 7 mm is also presented in [2] which covers 0.675 GHz to 1.05 GHz. Besides, [3] proposed a compact antenna with a smaller clearance of 5 mm. It covers the lower band from 0.8 GHz to 1 GHz. Moreover, a further smaller clearance of only 2 mm is used for antenna designs which cover 0.85 GHz to 0.96 GHz and 0.82 GHz to 0.97 GHz, respectively in [4] and [5].

Among the published papers mentioned above, the clearance is small for the antennas in [4] and [5], which is desirable for modern smartphone applications, while the others show a big clearance. The antennas, except the one in [5], use impedance matching networks which would introduce additional loss. Besides, they all show a limited bandwidth for the low-frequency band, except [2]. Frequency reconfigurable technique had also been proposed to cover 0.698 GHz to 0.96 GHz while the varactor diode would reduce the radiation efficiency [6]. Furthermore, when considering the user hand effect in practical use scenarios, it is desirable to have a miniaturized antenna with a small slot without extending to the long side of the substrate. It remains a great challenge to design a compact metal rim antenna with small clearance, compact size, and simple feeding structures without matching circuits. In this paper, a wideband and miniaturized metal rim antenna is developed based on a special material, the properties of which will be introduced next.

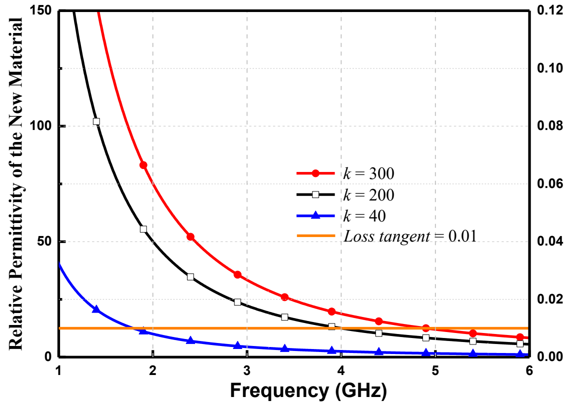

Fig. 1. The proposed material properties in terms of the permittivity and loss tangent.

II. New Material Properties

The proposed antenna is developed based on a new material developed at Liverpool whose permittivity is inversely proportional to the frequency square. Its relative permittivity can be expressed as:

$$\varepsilon_r = \frac{k}{f^2} > 1 \tag{1}$$

where ε_r is the relative permittivity, k is the material coefficient (unit: GHz^2), and f is frequency (unit: GHz). Fig. 1 shows the permittivity and loss tangent for different k values.

III. Antenna Design Based on the New Material

Fig. 2 shows the configurations of the proposed metal rim antenna. As shown in Fig. 2 (a), a traditional FR-4 substrate with a thickness of 0.8 mm, a dielectric constant of 4.3, and a loss tangent of 0.025 is used as the system printed circuit board (PCB) with a dimension of 150 mm × 75 mm. The substrate is surrounded by the metal frame with a thickness of 0.5 mm and height of 5 mm, at the top of which, there exists a gap cut in the middle of the metal rim. Besides the gap, there is a small area (shown in red) which is a portion of the substrate with the same thickness and here it is

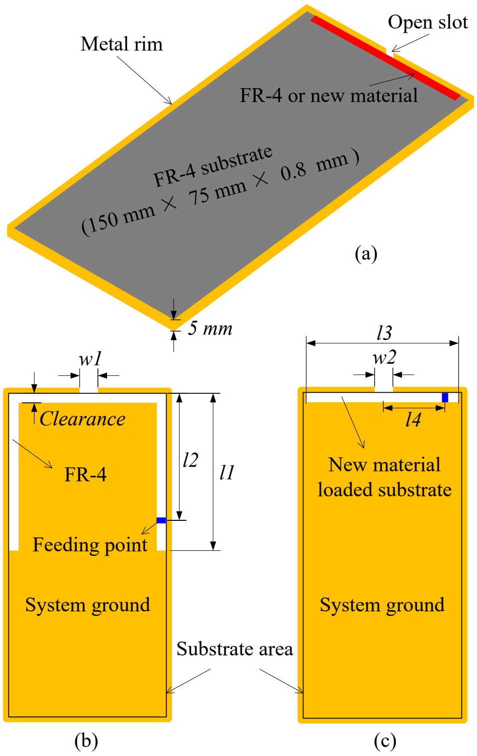

Fig. 2. Configuration of the proposed metal rim antenna. (a) 3D view, (b) bottom view of the antenna with traditional material FR-4, (c) bottom view of the antenna with the new material. *l1* = 30 mm, *l2* = 26 mm, *w1* = 2 mm, *l3* = 74.3 mm, *l4* = 32.2 mm, *w2* = 5.6 mm.

denoted as a material loaded area. Note that the loaded material is just above the clearance area in the ground plane and they are of the same plane size.

Fig. 2 (b) shows the bottom view of the antenna with the traditional material of FR-4. Fig. 2 (c) shows the bottom view of the new antenna with new material. It can be seen that the slot length (the same as the length of the loaded material) is within the width of the substrate, due to the higher permittivity of the new material used here (k = 40), in other words, the slot antenna is placed at the top side without extending to the long side of the substrate, which can reduce the user hand effect significantly. Here the case with traditional FR-4 is denoted as case#1, the case with a high constant permittivity of 77.1 is denoted as case#2, and the case with the new special material is denoted as case#3. Note that the permittivity of case#3 at frequency point of 7.5 GHz is the same as that of case#2, and the configurations of these two cases are the same for bandwidth comparison. The loss tangent of the loaded materials is set as 0.01 for all cases.

As shown in Fig. 3, for case#1 with FR-4, the impedance matching is poor even after optimization, and the potential maximum bandwidth (S11 < -6 dB at the band edges) covers from 0.822 GHz to 0.961 GHz. The open slot would extend to the long side of the substrate in order to cover the low-frequency band. For case#2 with a high constant permittivity, even though the antenna size is reduced significantly, its bandwidth (0.743 – 0.777 GHz) is very narrow, while it can cover a wider band of 0.732 GHz to 0.907 GHz with good

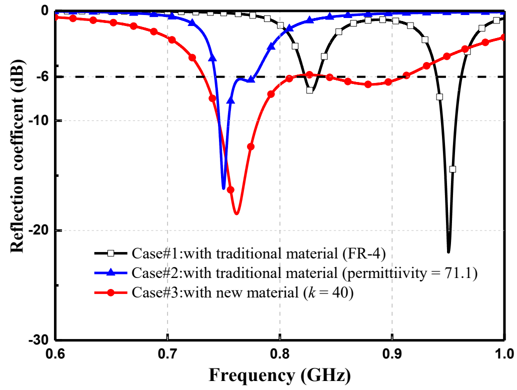

Fig. 3. Simulated reflection coefficient for different cases.

impedance matching for case#3 with new material. The antenna performance is being validated by measurements.

IV. Conclusion

A new metal rim antenna based on a special material with frequency-variant permittivity is introduced for smartphone applications. Compared with the antenna design with traditional materials, the new material loaded antenna shows excellent merits on the size reduction, bandwidth enhancement, small clearance, and simple feeding method without matching networks which is very promising for modern metal rim smartphone applications. The measured results and detailed working mechanism will be presented in the future.

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