

ARTIFICIAL DIELECTRICS FOR MOBILE ANTENNA DESIGN

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INTRODUCTION

Today's communication systems call for multifunction, low profile antennas, where reduction of size and cross talk are major design concerns. A typical system may involve a multitude of printed radiators that have to be packaged and operated in close proximity to each other. In a previous paper [1], a planar graded index lens has been proposed for both size reduction and isolation. A high permittivity superstrate lens provides miniaturization of individual radiators. On the other hand, a properly designed varying index profile prevents propagation of surface waves and hence improves isolation.

Realizing a given index profile is not an easy task. Conventional manufacturing techniques such as "material injection" or "molding" involve expensive processes. They also rely on traditional mixing formulas, which have limited applications [2-4]. This paper proposes a reliable method of designing an index profile and a cost-effective way of realizing it. The approach involves introducing vertical air voids inside a uniform host dielectric, the shape, size and density of which are optimized to achieve the given profile [5].

THEORETICAL RESULTS

A simulation-based approach is presented for synthesis of an artificial dielectric lens with a uniform or graded index profile. The underlying premise is to establish the equivalence between an artificial dielectric lens (with holes) and a uniform lens, both of which exhibit similar, or identical resonance and radiation characteristics (see Figure 1). Because the relevant parameter is the effective dielectric constant, the diameters of air voids are much smaller than the wavelength. The equivalence depends on the observation parameter and the type of application we are interested in.

In order to prove the concept of controlling the dielectric constant, different sets of numerical experiments we designed involving a dielectric disc placed over a slot ring antenna. The structure shown in Figure 2a was analyzed rigorously via a full-wave technique based on the finite element method (FEM). Air voids have been introduced by arranging the distribution of the dielectric and air cells as shown in Figure 2b.

In one set of experiments, first the permittivity of the uniform disc was varied and the front-to-back ratio (FBR) of the combined antenna was recorded. Then, air voids of varying density were introduced inside the disc of the same size and again FBR has been recorded. Finally, a data-driven model was constructed by relating the effective dielectric constant to the volume fraction based on identical front-to-back ratio as given by the solid curve in Figure 3. Indeed a computation performed on two lenses, deemed equivalent by the model, showed that the radiation patterns differed by a maximum of 0.1dB. A similar experiment was carried out where equivalent models were constructed based on the resonant frequency of the slot ring radiator. The result is shown by the dotted curve in Figure 3.

EXPERIMENTAL RESULTS

This section will demonstrate the usefulness of controlling the local effective dielectric constant for the purpose of matching a resonant antenna. Figure 4 shows a square slot loop fed by a coax. First, the best match was found by changing the slot width from 0.5" to 0.75". As seen from Figure 5, as the slot width increases, the match continues to improve and reaches its best level for 0.67" wide slot. Further increasing the slot width worsens the match. It is known that increasing the slot width increases the input impedance. The same effect can be achieved by lowering the permittivity of the substrate around the feed region. Figure 6 shows the result of progressively removing dielectric material from underneath the coax feed while keeping the slot width at 0.5". When the volume fraction of air voids reaches 54.5%, the quality of the impedance match is the same as that obtained for a slot width of 0.67".

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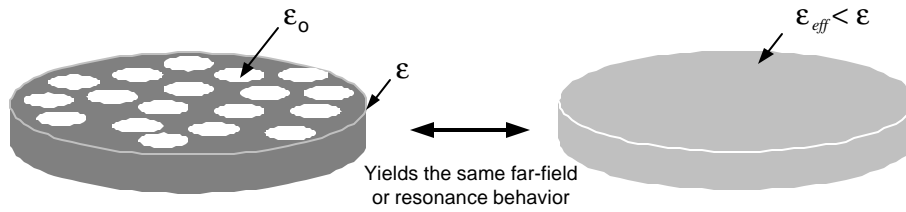


Figure 1: Schematic illustration of the equivalence between two dielectric disks. One having a high dielectric constant host material with air voids and the other having a uniform distribution of a smaller dielectric constant.

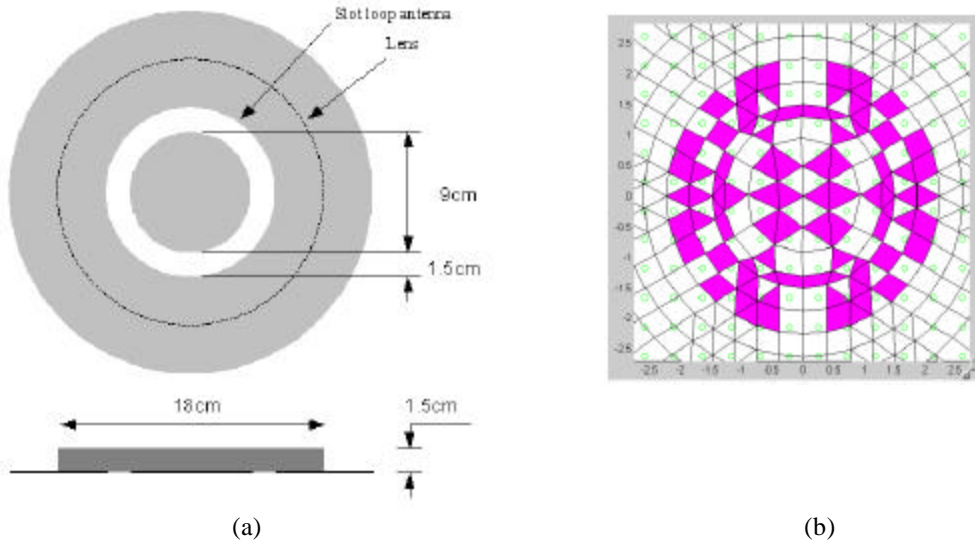


Figure 2: (a) Dielectric disk lens over a slot ring radiator, (b) introduction of air voids in finite element method analysis.

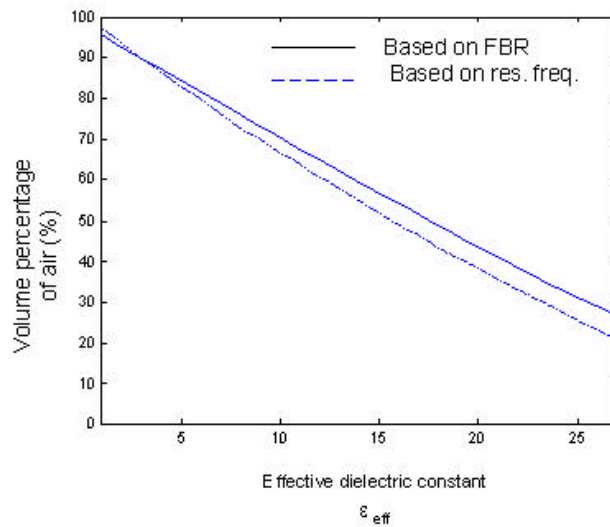


Figure 3: Empirical data showing the volume percentage of air required to achieve a given effective dielectric constant based on identical FBR (solid), and resonance frequency (dashed).

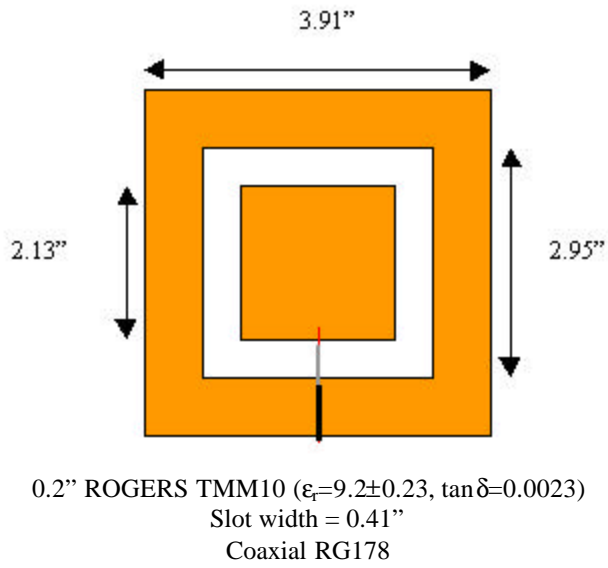


Figure 4: Dimensions of a square slot loop used for the local impedance tuning study

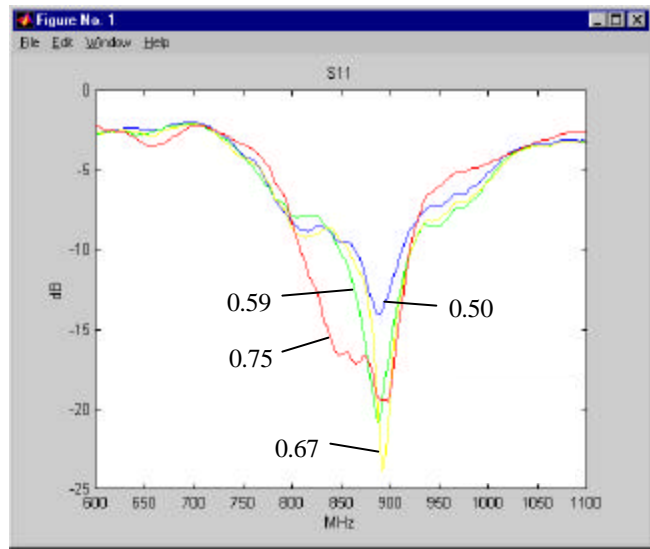


Figure 5: Measured S_{11} of square slot loop for different slot widths.

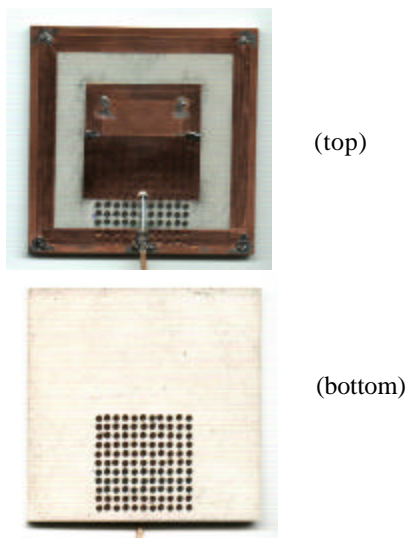


Figure 6: Circular holes punched around the feed location in order to decrease the effective permittivity hence to increase the input impedance.

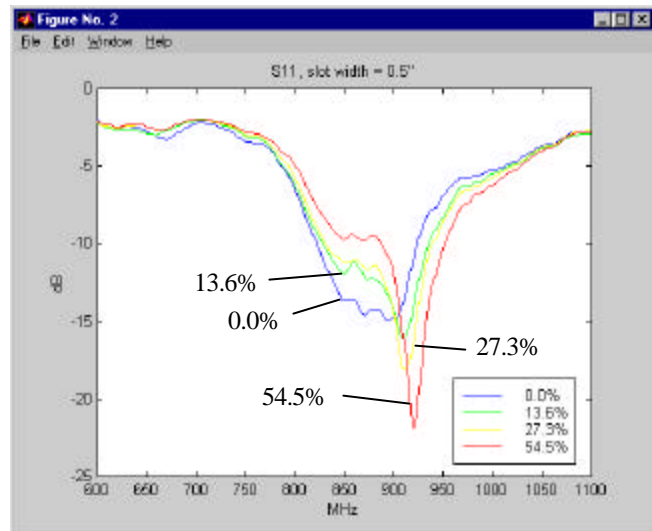


Figure 7: Measured S_{11} of the square slot loop for different volume fractions of air void.