A Physical Interpretation of Effective Dielectric Properties of Slow-Wave Transmission Lines in Small Antenna Applications

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With the rapid growth in advancements in modern communication technology, the demand for small and miniaturized antennas has increased during the last decades. Such antennas have found special attention as they reduce the cost, volume, feed blockage, and mutual interferences. The main requirement in the antenna miniaturization is to increase the electrical path length and thus slow the phase velocity [J. L. Volakis, et al, "*Small Antennas: Miniaturization Techniques and Applications*". New York: McGraw-Hill, 2010]. This will, in turn, shift down the lower operating frequency and reduces the antenna size at the designed operating frequency. There are several ways to impose the phase delay such as material loading, inserting lumped elements, and shaping the antenna structure itself. The latter technique effectively enlarges the electrical length without increasing the antenna size. Examples are meandering, zigzagging, slot loading, and bending. All of them lead to increase the effective electrical length of the antenna and subsequently lower the operating frequency. A few miniaturized antennas have been recently reported in the literature using antenna shaping method. However, to the best of our knowledge, study of the dielectric properties of such transmission lines is missed in miniaturized antenna applications.

In this paper, first, several meandered transmission lines are reviewed, which can be used for the antenna miniaturization. Examples with a square-pulse shape, zigzag, and rectangular-pulse shape on a pedestal are investigated. These shapes basically enlarge the effective electrical length, which results in slowing the phase velocity and thus lowering the operating frequency. Therefore, the size of the antenna is miniaturized. Then, the aforementioned transmission lines, suspended in the air, are treated as an equivalent dielectric medium in the form of a two-port network. Consequently, the effective dielectric constants of the lines are extracted from the scattering parameters of the network. It is shown that such undulated lines, even with a supporting material such as air, behave like dielectric materials with effective dielectric constants of considerably much larger than that of air. The so-called effective dielectric constants of the lines are useful in understating their physical interpretation in the area of antenna miniaturization. The corresponding results of the undulated transmission lines and their applications in compact antennas will be discussed and presented in the conference.