Analysis of surface-plasmon-like modes under an engineering perspective

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Abstract: In this communication we show how one can exploit equivalent circuits to analyze surface-plasmon-like modes (slit and hole arrays, Sievenpiper mushrooms and coaxial hole arrays) and to propose new designs with outstanding features.

Microwave engineers have been using successfully circuit models to develop their work for more than a century. The powerful platform provided by this circuitry concept may benefit the analysis of surface plasmon polariton [1, 2] as well as, for instance, the design of novel geometries supporting surface-plasmon-like modes in the framework of perfect electric conductor [3]. These so-called spoof-plasmons have a great potential at THz frequencies, where surface plasmon polaritons become undesired delocalized normal to the surface: Sommerfeld-Zeneck waves [4].

Surface plasmon polaritons are TM waves, and thus, they are supported by an inductive surface. Therefore, the condition to have a surface-plasmon-like mode, in other words, a TM wave, is to have, in engineering terms, an equivalent circuit model of the surface impedance of the form $Z_s = j\ X$ [5]. Moreover, in order to mimic the surface plasmon frequency, this surface impedance should have the inductive behaviour below a resonance, and afterwards, it should change its character to capacitive or resistive. Indeed, this picture is nothing but the translation to engineering words of the definition of surface plasmon polariton: collective electron density oscillation, where the term oscillation should make researchers look towards resonant circuits.

With the assistance of this circuit interpretation, we revisited slit and hole arrays, Sievenpiper mushrooms [6] and the latest proposed coaxial hole arrays [7] to derive the properties of them and to envision their dispersion diagram. We show that all of them support a surface-plasmon-like mode but hole arrays with their equivalent circuit models, the dispersion diagram and the eigen-mode analysis.

Once these structures available in the literature are analysed, we propose a complementary-split-ring-resonator-based surface-plasmon-like wave which exhibit higher confinement and wider frequency of operation [6], together with elliptical coaxial hole arrays displaying dual-band response. As a practical outcome, we design straight planar waveguides and Y-splitters with these last topologies.

References:

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