Chain of Metamaterial Nanospheres as Leaky-wave Nanoantennas at Optical Frequencies

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The theory for designing a traveling-wave or a leaky-wave antenna is well established at microwave frequencies. At these frequencies usually a waveguide structure with some radiating defects or corrugations periodically arranged in space can produce a guided beam that leaks some energy into free space. Under proper conditions on the periodicity and the guidance of the energy, this may produce a directive beam with potential applications in several fields. The advent of metamaterials, i.e., artificially engineered materials with unconventional properties not common in nature, has raised new interest in different areas including the leaky-wave antenna design. In particular, a proper design of planar metamaterial circuit boards has been shown by others to produce a compact leaky-wave antenna with interesting performance, in terms of the possibility of scanning the angle of radiation from end-fire to back-fire by varying the frequency of operation, without any cut-off at broadside [1, 2].

Extending these concepts to the optical frequencies can offer exciting possibilities and useful applications. However, such extension does not only involve the scale reduction, since materials (e.g., noble metals) behave differently in different frequency regimes. The recent interest in plasmonic resonances and related phenomena, however, has raised the attention on a possible new paradigm for extending the circuit concepts from lower frequencies into the visible domain. We have shown in [3] how nanocircuit elements can be envisioned at these frequencies and how they can be properly connected in order to synthesize a complex nanocircuit. In [4] we have followed this analogy to consider optical nano-transmission-lines by properly arranging nanoinductors and nanocapacitors. Following the same analogy, and exploiting linear chains of plasmonic particles interleaved with non-plasmonic gaps, here we show theoretically how it is possible to design highly directive leaky-wave antennas at optical frequencies with future potentials in communications and nanotechnology. A different way of designing leaky-wave antennas using periodically modulated epsilon-negative nanorods has recently been studied theoretically [5]

In the present work, we show the conditions on the plasmonic particles composition and on the geometrical properties of the chain for supporting such resonant modes and consequently for building directive nanoantennas at optical frequencies. We also propose some design examples and we verify the results with full-wave simulations utilizing realistic materials (e.g., silver) with dispersive properties and ohmic losses included.

REFERENCES

1. Grbic, A. and G. V. Eleftheriades, *IEEE Trans. Antennas Propagat.*, Vol. 50, 1494, 2002.
2. Lim, S., C. Caloz, and T. Itoh, *IEEE Microwave & Wireless Components Lett.*, Vol. 14, 277, 2004.
3. Engheta, N., A. Salandrino, and A. Alù, PRL, Vol. 95, 095504, 2005.
4. Alù, A. and N. Engheta, *Proc. of URSI GA*, New Delhi, India, Paper No. 99, 2005.
5. Li, J. and N. Engheta, "2005 annual meeting of the optical society of america," *Frontiers in Optics*, Tucson, Arizona, October 16-20, 2005.