Frequency Beam Scanning and Gain Enhancement Properties of PBG-Antennas

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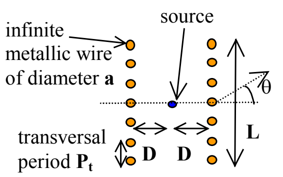
The main purpose of this communication is to present the frequency beam scanning possibility of PBG-antennas and the relationship with high gain property. To this end, we will first remind the gain enhancement phenomenon and then generalize the results to the steered beam antennas.

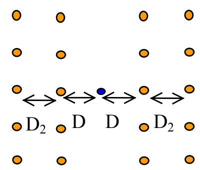
The first analysis and design of high gain antenna using periodic structures can be attributed to Von Trentini, where he used a simple Fabry-Perot (FP) cavity having a single partially reflecting surface (G.Von Trentini, *IRE Trans. on Antenna and Propagation,* vol. 4, 666-671, 1956). We will show that for FP structures, the angular selectivity $\Delta\theta_{3dB}$, i.e. the antenna half power beam width (HPBW), is related to the to the frequency selectivity, i.e. the quality factor Q of the structure by the following relationship : $\boldsymbol{\Delta\theta_{3dB} \approx 2/\sqrt{Q}}$. More recently the defect mode of multiple layer PBG structures has been used to enhance the antenna directivity gain (M. Thevenot et al., *IEEE Trans., MTT*, vol. 47, no. 11, 1999). However, the frequency beam scanning property of PBG antennas or FP cavities has not been sufficiently emphasized on in the literature and is not well known to the antenna engineers. Hence, we propose here to focus on this aspect of PBG-antennas.

Figure 1a presents a simple PBG-antenna where the partially reflecting surfaces are constituted of single row of metallic rods. The beam angle of this structure as a function of frequency is given by the equation $\boldsymbol{\theta_s = \arccos(\varphi_r c/(4\pi f D))}$, where φ_r is the phase of the reflection coefficient of the cavity surfaces. In *fig. 2a*, θ_s is plotted versus the frequency. We present in *fig. 2b-g*, the radiation patterns for the frequencies corresponding to the steered beams θ_s= 10°, 20°, 30°, 40° and 50°. For the steered beam case, the relation between angular and frequency selectivity becomes : $\boldsymbol{\Delta\theta_{3dB} \approx 2(\arccos(\cos\theta_s - \cos\theta_s/(2Q)) - \theta_s)}$.

The second purpose of our communication is to show the effect of multiple layer PBGs on the antenna radiation pattern. Consider the PBG structure 2 (*fig. 1b*). For D_2=D, the radiation pattern for broadside beam (*fig. 2h)* seems to be more directive than the previous one (*fig. 2b*). For D_2=2D a "double beam" appears due to the coupling between cavities of the same resonance frequencies *(fig. 2i-j)*. This property may be used for "difference pattern" applications.

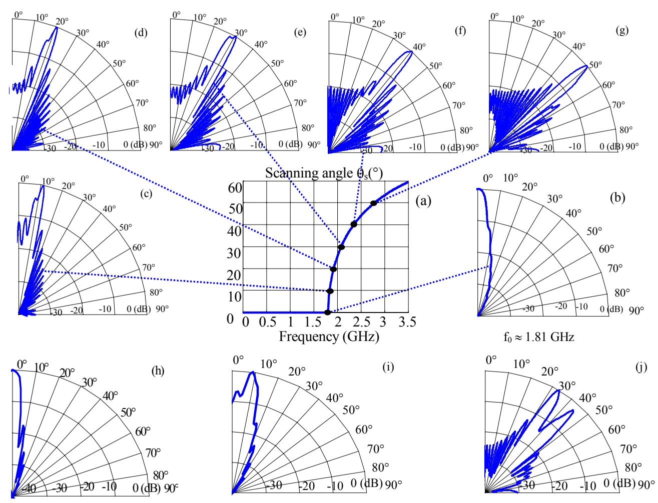


(a) structure 1
***(Pt**=10mm **a**=2mm **D**=40mm*
***L**≈26λ₀)*



*(b) structure 2 (**Pt**=20mm*
***a**=2mm **D**=40mm **L**≈26λ_0)*

Figure 1: Geometry of PBG-structures



Figures 2: (a-g) *Frequency beam scanning with structure 1.* (h) *Broadside radiation pattern for structure 2 where D_2=D ($f_0 \approx$1.67GHz).* (i-j) *Broadside and steered patterns for D_2=2D. ($f_0 \approx$1.58 & 2.17GHz resp.)*