BAND GAP CHARACTERISTICS OF MEDIA WITH LATTICE STRUCTURE

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We consider waves in a medium with lattice structure. Calcite, quartz, etc are examples of such media. Lattice spacing of such naturally occurring media are very small and they can be treated as continuum for most applications except at very small wavelengths such as those of X-rays. However people have built artificial crystals with much larger lattice spacing for applications at optical frequencies. If the lattice spacing becomes comparable to the wavelength of the incident wave, the interference effects play a central role in determining the electrical characteristics of such media. The earliest manifestation of such effects is the Bragg scattering phenomenon according to which waves at certain angles of incidence can have total reflection. Bragg equation is based on a simple consideration of the phase difference between waves reflected by 2 adjacent lattice planes. However in a medium with low absorption and perfect lattice structure, multiple scattering becomes very important in determining the properties of the medium.

Our model of the medium consists of a lattice structure with spacing d where each lattice plane consists of a distribution of atoms. This medium occupies a half space and is excited by a plane wave from above. We are interested in the scattering characteristics of this half-space medium. First we study the characteristics of a single lattice plane (all lattices planes are assumed to be identical). We calculate the reflection and transmission coefficients of a single lattice plane. We refer to this as single scattering coefficients. Waves in a lattice structure undergo multiple scattering which are next described in terms of single scattering coefficients. The coefficients of waves inside the lattice structure are expressed in the form of recurrence relations. Hence the coefficients of upward and downward traveling waves are found to be governed by second order difference equations. On solving these equations we arrive at the multiply scattered reflection and transmission coefficients of our half space medium.

The coefficients thus derived display several interesting band gap characteristics. Numerical results show that there exist complete stop bands and pass bands. The lattice spacing is a key factor that influences the number of such bands and their widths. The width of the dominant stop band can be quite wide as large as tens of degrees in some cases. On the other hand, the widths of the pass bands are significantly narrow. The number of stop bands increases with lattice spacing. However, when the lattice spacing becomes very small all stop bands vanish. We noticed that the number of stop bands for vertical polarization is much larger than that for the horizontal polarization. Also the number of stop bands for the case when the dielectric constant is lesser than unity is much larger than the case when the dielectric constant is greater than unity.

♣ SM thanks the US Air Force Office of Scientific Research for support