Coherent Scattering of Radio Waves in the Ionosphere

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There are documented observations to indicate that certain ionospheric plasma processes can give rise to intense radar echoes comparable to those from space objects. Strong radar echoes with short durations were recorded near the equator. The radar echoes have a fast rise time of order of a few milli-seconds. They last for several tens of milli-seconds or less. These radar bursts usually occur at the valley of ionospheric F region, but, at times, two or more altitudes " explode " simultaneously while with no noticeable activity in the quiet regions in between. Occasionally, several successive radar echoes were recorded with inter-pulse periods of order of a few seconds. The close correlation between the appearance of these intense radar bursts and the occurrence of lightnings from local thunderstorms was found. How the ionospheric plasma processes trggered by lightnings can produce intense coherent scattering of radar signals ? We have investigated this problem by examining the electromagnetic effects produced by lightnings, including acoustic gravity waves, transient DC electric field, and VLF waves. It is found that the transient DC electric field and VLF waves are most likely responsible for exciting short-scale plasma modes, which can cause coherent scattering of radar waves. These plasma modes have geomagnetic field aligned nature, namely, they have large aspect sensitivity. In other words, their radar cross sections peak sharply at the aspect angle of 90 degrees with respect to the earth's magnetic field. Different type of coherent scattering of radar signals was seen at Millstone Hill, Massachusetts with the MIT 440 MHz radar. We believe that it was caused by the excited ion acoustic modes. These plasma modes, by contrast, are not field-aligned. They have large radar cross sections in a broad range of aspect angles. When they are detected, the radar spectrum exhibit asymmetric ion lines. In cases, symmetric ion lines were observed to become asymmetric gradually with altitudes. This fact leads to the natural speculation that geomagnetic field aligned currents distort the ion lines and may, possibly, be the geophysical process causing the coherent scattering of radar signals. However, after a close examination of the geophysical conditions producing the observed asymmetric ion lines, we find that this process require very intense currents and a large ratio of electron temperature and ion temperature. Further, if this process is indeed active in ionospheric plasmas, it will produce the concerned plasma modes over a large range of altitudes. This, however, seems to contradict the observations that this coherent scattering process only appeared locally in the topside ionosphere. Our theoretical analysis of this problem centers on local plasma processes which are able to cause the observed coherent scattering of radar signals. We will show that nonlinear mode coupling of Langmuir wave turbulence produced by particle precipitation can generate ion acoustic waves. These ion acoustic waves are forced ion acoustic modes because their frequencies, determined by the beat frequencies of Langmuir waves, are not necessarily their characteristic frequencies. If these forced ion acoustic modes propagate in certain preferred directions, they can give rise to the observed asymmetric ion lines. Our proposed field experiments and laboratory experiments for the further investigation of such coherent scattering of radio waves will be discussed.