**Propagation of ultra-short infrared laser pulses in random dilute medium of water droplets and aerosols and imaging through clouds***

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We describe an approach to high-resolution synthetic-aperture-type imaging through clouds, in which the transmitted signal is a coherent train of short rise/fall infra-red pulses with a varying (chirped) inter-pulse time intervals. Processing of the received pulse involves filtering (analogous to the conventional matched-filter techniques) associated with the chirp characteristics. Our approach addresses two man challenges of efficient imaging: (a) achieving sufficient signal penetrability (b) achieving high image resolution. In the considered scheme, high signal penetrability is achieved through the presence of relatively low frequencies (in the range of $\sim$ 100 GHz to $\sim$ 1 THz) in the spectrum of a single pulse; a sizeable contribution of such frequencies is due to the short rise and fall times of the pulse. In such circumstances, dispersion in the medium (a dilute suspension of water droplets) gives rise to reduced absorption of the lower frequencies and an approximately power-like (rather than exponential) attenuation of the signal, characteristic of Brillouin precursors.

A potential difficulty in using wide-band pulses is that the same dispersive mechanism which improves signal penetrability, causes also a significant distortion of the pulse and its effective elongation, and thus a possible resolution loss. However, in our scheme the range resolution is controlled not by the lengths of the individual pulses, but rather by the bandwidth of the inter-pulse-interval chirp. That bandwidth may be sufficiently large to achieve a resolution typical of sub-millimeter radar.

We demonstrate that the proposed use of the large number of pulses in the train leads to a significant increase of the total power of the signal. In addition to increased cloud penetrability, the proposed approach allows reduction of the effects of atmospheric absorption: by varying the lengths of the pulses one can maximize the fraction of power emitted within atmospheric absorption windows.

We also show that the proposed use of the large number of pulses in the train leads to a significant increase of the total power of the signal. While the proposed inter-pulse chirping technique provides high range resolution, a high cross-range resolution can be achieved in analogy to the usual synthetic-aperture imaging. We discuss resolution dependence on the medium properties of the clouds and the atmosphere, as well as on the parameters of the signal, such as the shape of the pulses, chirping, and the beam divergence and the resulting footprint size. These estimates are illustrated by examples of two-dimensional image reconstruction of a realistic terrain area, based on synthetically generated data.

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