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Radar Applications of Gigawatt Sources at Millimeter Wave Frequencies

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ABSTRACT

The high transmit powers provided by free electron laser (FEL) sources in combination with the narrow antenna beamwidths achievable at millimeter wave (MMW) frequencies offer potential for use in a number of radar applications. Potential applications of high power millimeter wave sources include satellite imaging, low angle radar tracking, radar astronomy, and a number of other possible applications such as atmospheric research, space debris detection, and space vehicle tracking.

INTRODUCTION

The Georgia Tech Research Institute has been investigating the potential radar applications of millimeter wave FEL sources for the Lawrence Livermore National Laboratory in Livermore, California, USA. The use millimeter wave frequencies is attractive because very narrow antenna beamwidths can be achieved using reasonable aperture sizes.. This, coupled with the FEL's high transmit powers and instantaneous bandwidths exceeding several gigahertz provide the potential of achieving orders of magnitude improvement of sensitivity and resolution over present radar systems.

SATELLITE IMAGING

The primary radar application of the FEL source appears to be for tracking and imaging of satellites at ranges out to geosynchronous orbits. In the monostatic radar application (collocated transmitter and receiver), the FEL-based radar would be ground based (or ship based) due to the large size of the FEL transmitter, the antenna, and the power source requirements. The use of wideband waveforms enables high range resolution; 1 to 2 GHz bandwidths enable range resolution of approximately 10 cm[1]. The Doppler motion due the satellite trajectory would enable the use of inverse synthetic aperture radar (ISAR) processing to provide corresponding cross-range resolution on satellites that are not in geosynchronous orbit. A bistatic radar application, depicted in Figure 1, would utilize a ground-based transmitter and a satellite-borne receiver. The bistatic configuration could provide cross-range imaging of geosynchronous satellites by using the motion of the satellite receiver and synthetic aperture radar (SAR) processing[1]. A number of candidate high-range-resolution waveforms and receiver architectures have been developed to satisfy the FEL requirements. Candidate waveforms include discrete phase coded waveforms, many of which are robust relative to modulation error and generally provide a thumbtack ambiguity surface such as shown in Figure 2. Examples of phase coded waveforms include linear recursive sequences and frank polyphase and associated sequences. The associated range sidelobe performance is depicted in Figure 3. In addition, stepped-frequency waveforms are under investigation. Waveform selection is critically dependent upon the interaction of waveform modulation and the amplitude/phase responses of the FEL. A coherent-receive architecture to provide intrapulse and interpulse coherence has been devised.

RADIO ASTRONOMY

The high transmit power coupled with the narrow antenna beamwidth could provide an active source for radio astronomy. In addition to providing a transmit pulse for its own receiver, The FEL source and associated antenna could transmit pulses for the present passive radio telescopes such as the Very Large Array near Socorro, New Mexico, or the 45 m MMW radio telescope at Nobeyama, Japan[2]. This application may not in itself justify the costs associated with the development but could be a secondary application of the transmitter source.

HIGH POWER CONSIDERATIONS

The generation and transmission of peak powers of a gigawatt present a number of potential problems which need to be considered in the design of the radar. The use of beam waveguide for coupling the FEL source output to the antenna would provide the needed power handing capability while reducing the losses associated with waveguide transmission methods[3]. Additional consideration must be given to protecting the receiver during the transmit pulse time.

ACKNOWLEDGEMENT

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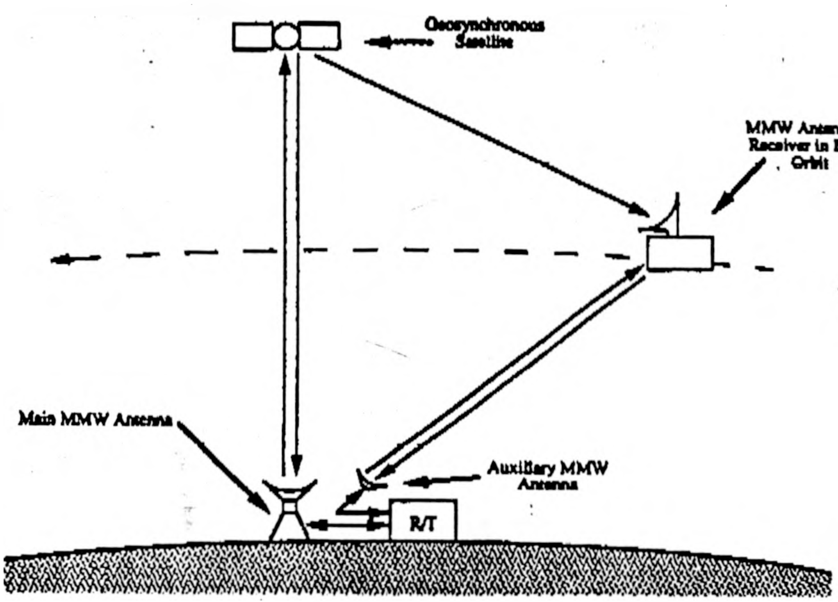

Figure 1. Bistatic radar configuration for satellite imaging

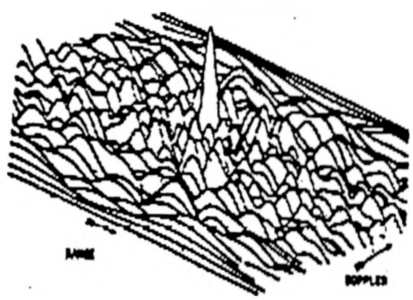

Figure 2. Ambiguity function

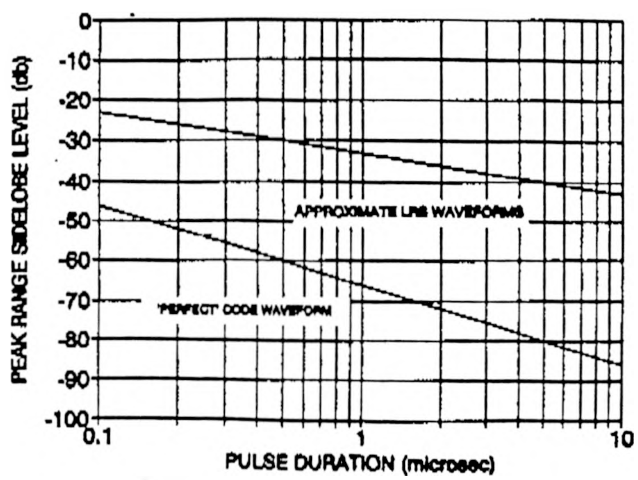

Figure 3. Range sidelobe performance (bandwidth = 2 GHz)