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EFFICIENT WIDEBAND PROCESSING WITHOUT SUBBANDING (PREPRINT)

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14. ABSTRACT
A new method for wideband spatio-temporal processing in the context of clutter mitigation and target detection is addressed in this paper. The frequency dependent, spatio-temporal steering vectors, are separated using a series expansion that depends on a sequence of Bessel function terms, and this is used to focus data vectors corresponding to various frequency components to a single frequency component. As a result, narrowband space-time adaptive processing (STAP) can be carried out on the focused data vector for clutter mitigation and target detection.

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wideband space-time adaptive processing, Bessel Function Expansion, Frequency Refocusing

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Efficient Wideband Processing Without Subbanding*

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Wideband operation in a space-time adaptive radar significantly complicates the processing chain from both an algorithmic and hardware/software implantation point of view. While every radar instantiation and operating scenario has its own unique requirements and characteristics, certain key justifications can be stated in generality.

One significant trend in radar development that is providing the impetus for wideband operation is airborne *GMTI radar for tracking of ground mobile vehicles*. Original GMTI radars such as JSTARS, were not designed to track individual ground targets but rather to provide gross information on troop/vehicle movement.

In recent times, our adversaries have switched tactics from a traditional force-on-force model to asymmetric and even terrorist tactics that require a major shift in GMTI radar operation. Specifically, requirements have evolved away from gross movement indications and warnings (I&W) to *individual tracking of high value targets*.

Keeping track of a small group of targets or even a single high valued target requires a far more capable GMTI radar than that required for I&W. There exists a multitude of potentially deleterious effects present in real-world GMTI scenarios that can interfere with an automated tracker's (or even human radar operator's) ability to maintain track. These include, but are not limited to, background ground traffic (i.e. "confusers"—intentional or not), false alarms (particularly in strong heterogeneous clutter), and "drop outs" caused by either line-of-sight blockage or radial target speeds dropping below the minimum detectable velocity (MDV).

The objectives of an efficient wideband processing technique are to use the entire wideband frequency information, avoid subbanding and take advantage of narrowband STAP. In order to achieve the above objectives, one must understand the problems associated with wideband operations.

One of the problems associated with wideband operations is frequency dependent steering vector and array gain pattern. Recall that in the narrowband case, a time-delay in a signal appears as a frequency insensitive phase delay [1].

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However, in the wideband case, the time-delay is a frequency sensitive phase delay. In this case, with $x_1(t) \leftrightarrow X_1(\omega)$ representing the reference sensor output, for a target along θ the second sensor output is given by

$$x_2(t) = f(t - \frac{d \sin\theta}{c}) \tag{1}$$

where d represents the interelement spacing. In the frequency domain, it can be represented as

$$X_2(\omega) = F(\omega) e^{-j\omega \frac{d \sin\theta}{c}}. \tag{2}$$

Clearly, the phase shift in (2) is a function of the frequency ω. Thus, the frequency dependent spatial steering vector is given by [2, 3]

$$\underline{a}(\omega, \theta) = \left[1 \quad e^{-j\omega \frac{d \sin\theta}{c}} \quad \cdots \quad e^{-j\omega (N-1) \frac{d \sin\theta}{c}} \right]^T. \tag{3}$$

The sensitivity of phase delay to frequency introduces the beam blurring in the wideband scenario. With

$$\underline{e} = [1 \;\; 1 \;\; \cdots \;\; 1]^T , \tag{4}$$

the wideband array gain pattern is given by

$$G(\omega, \theta) = \left| \underline{e}^* \underline{a}(\omega, \theta) \right|^2 = \left(\frac{\sin\left(\frac{N\omega d \sin\theta}{2c} \right)}{\sin\left(\frac{\omega d \sin\theta}{2c} \right)} \right)^2 . \tag{5}$$

Notice that the array gain pattern in (5) is frequency dependent. Fig. 1 shows the array gain pattern as a function of the frequency and azimuth angle. A 14-element array is used here and the array is assumed to operate at 435MHz with 200MHz of bandwidth. The interelement spacing is 0.33 meter. From Fig. 1 the array gain pattern varies as the frequency changes and its mainbeam width depends on frequency.

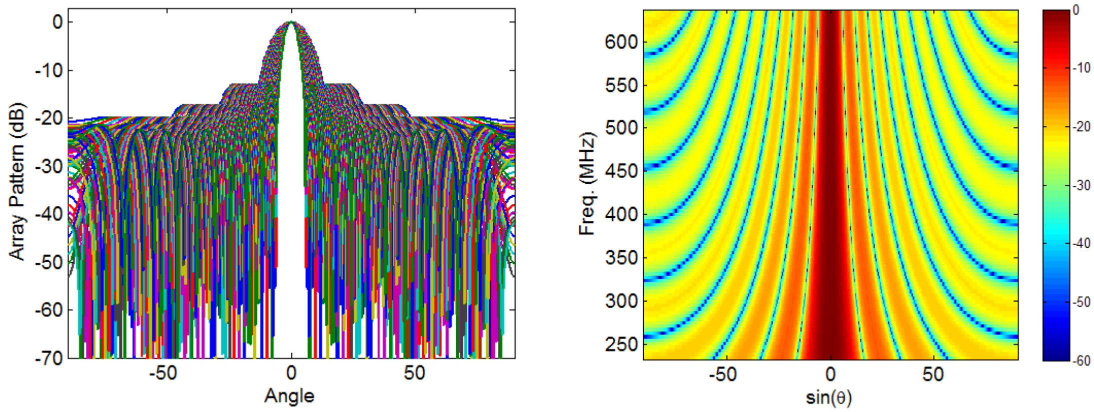

Fig. 1 Array gain pattern as a function of frequency and angle (before refocusing).

The undesirable phenomenon – frequency dependent wideband array gain pattern and steering vector – affect the target detection in wideband operation. One must reduce the antenna dispersion in wideband operation. One question is how to pre-process the wideband data so that the mainbeam width is frequency invariant and how to pre-process the frequency dependent data vector so that the "fast data" vector is frequency independent.

A frequency refocusing technique for wideband STAP is proposed here. Notice that the frequency and azimuth variables in the wideband array gain pattern shown in (5) are non-separable. Using Bessel function expansion, the non-separable wideband array gain pattern can be made separable, thus, making frequency refocusing possible. The goal of the frequency refocusing technique is to focus wideband clutter returns from different frequencies to a single frequency ω_o without subbanding and then perform narrowband STAP on the focused data.

Fig. 2 shows the frequency refocusing technique. The frequency refocusing operator acts at a lens here to focus all the data into a single frequency. In Fig. 2 wideband clutter returns from multiple frequencies are focused into a single frequency ω_o and narrowband STAP is applied to the focused data.

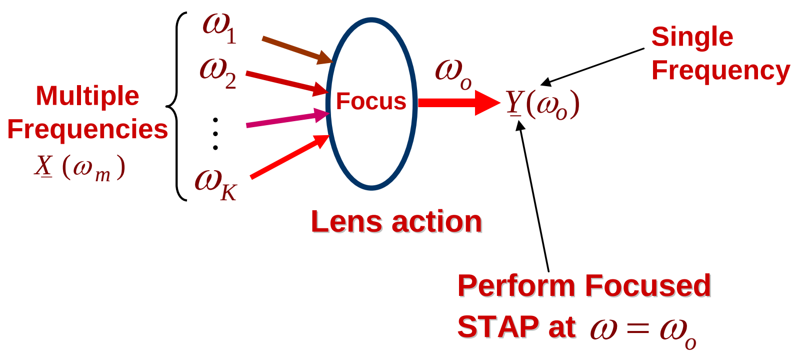

Fig. 2 Frequency refocusing for wideband STAP.

Fig. 3 shows the wideband array gain pattern after frequency focusing. From there, the mainbeam width of the gain pattern are clearly frequency independent.

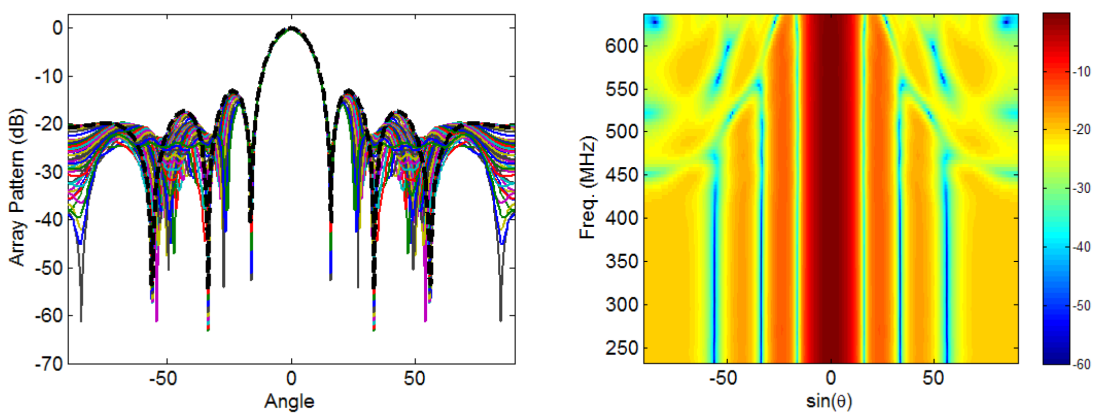

Fig. 3 Array gain pattern as a function of frequency and angle (before refocusing).

Fig. 4 shows the angle-Doppler output using STAP processing on the refocused wideband data. A 14-sensor array with 16 pulses is considered here. The operation frequency of the array is 435 MHz with 200 MHz bandwidth. A target is injected at 0^o with velocity of 40m/s. Notice that unlike subband processing, only one STAP processing in required in the present approach. Details of the frequency focusing method processing will be described in the full paper.

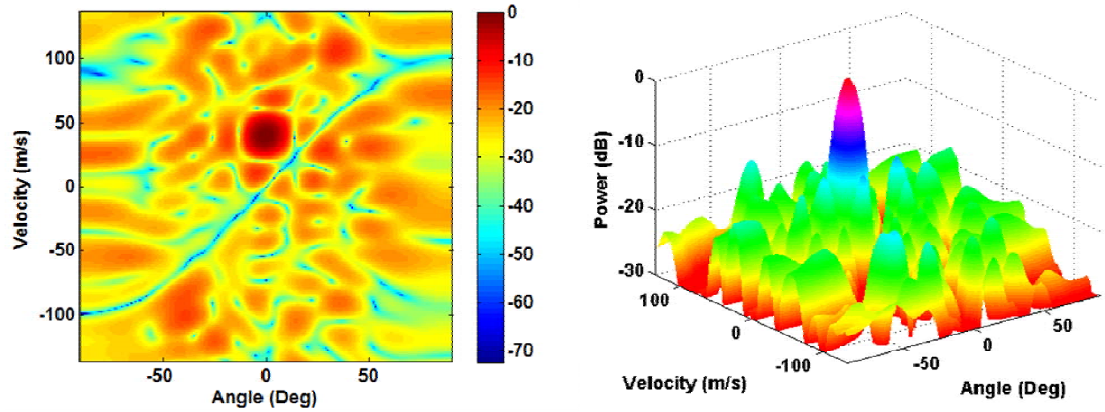

Fig. 4 Angle-Doppler output using STAP processing on the refocused wideband data.

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