Session Summary -- Signal and Data Processing

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Signal and data processing is often regarded as an inevitable, but undesirable part of the work in the MST community. Researchers are urged to devote themselves to scientific interpretation of wind profiles rather than playing with 'low-level' signal processing toys. Also, it is in some sense true that standard procedures have been established to a level that a practical data processing system for a new radar can be constructed without developing a new algorithm.

We found, however, in this session that there are a number of new ideas worth implementing to existing systems, and also that there still remain problems to be given better solutions in order to make our data more reliable. Here we briefly summarize the issues presented and discussed in the session.

1 Overview (R. F. Woodman)

Recent developments in the speed of personal computers motivate an analysis of optimum processing setups which would take advantage of all the available information in a backscatter radar experiment, without considering the previous digital processing limitations. This is certainly true in experiments with underspread targets —MST targets in particular— where signals are sufficiently slow to allow direct FFT techniques on the pulse to pulse signal series. Multiple receiver and multiple frequency experiments can be considered as a multiple dimensional Gaussian process, where the information is contained in multiple- dimensional second moment (covariance) matrices, or their Fourier transforms. It is some time convenient to process linear combinations of these processes. The linear and statistical operations are many times commutable. This allows some of the operations to be performed numerically instead of analogically. It also allows to perform them after statistical processing, reducing the numerical processing burden. The Butler matrix and post-statistical steering is an illustrative example.

The processes are usually non-stationary, short integration estimates of the statistical parameters are related to time varying medium state parameters. They generate themselves other time series at a longer time scale. Statistical processing of these series is necessary. In certain cases they produce independent estimates of the same primary medium parameters. The case of velocities obtained by Doppler shift and classical space receiver techniques is considered as an example.

The parameter estimation problem is considered. Inversion techniques using models of the instrument and the medium is presented as optimum. The continuity of the parameters in altitude (space) and time, when it exists, should be taken advantage of, by modeling profiles in the inversion algorithm.

2 New pulse compression schemes

The complementary codes, which is most commonly used for the pulse compression in MST applications, are found to have a room for improvement (Spano, Ghebrebrhan and Spano). By choosing optimum series of complementary pairs, the code sidelobes due to truncated ranges, interferences, and non-linearity of the system can be minimized. The performances of the new codes are also demonstrated by actual examples of MST radar data in the session of New Hardware Developments and Systems.

3 Estimation of the echo power spectrum

Since most of parameter estimation procedures are based on the estimated echo power spectra, their accuracy is of crucial importance. Two commonly used procedures for determining the hack ground noise level are compared (Petitdidier *et al.*). Although presented in the session of New Hardware Developments and Systems, Hocking *et al.* proposed methods to reduce the effect of interferences. One is to choose a wide FFT window and to take only the central part which contains the atmospheric echo, instead of the conventional coherent integration and the narrow FFT window. This procedure avoids aliasing of aircraft clutters. The other is to remove the trend from the time series before applying FFT, which reduces the spreading effect of ground clutter spectrum.

An efficient method is proposed to estimate narrow spectral feature by using selective filtering (Woodman and Ragaini). It largely reduces the computational time by demodulation and lowpass filtering, which converts the desired frequency band into the baseband effectively.

The effect of system non-linearity on the estimated correlation functions, which is used in the full correlation analysis, are examined (Meek). The receiver overloading is the typical cause of such a problem.

4 Spectral parameter estimation

The most popular issue in the signal processing is still the optimum method of finding proper spectral peaks. Classical method of taking the first three moments of each echo power spectrum and removing outliers afterward is simple, hut results in an appreciable loss of information. Proposed new approaches are characterized by a combination of a guided peak finding followed by adaptive screening of false peaks (Anandan *et al.*, Delage *et al.*). Instead of finding a single peak from each echo power spectrum by taking the first moment, it is getting common to choose multiple candidate of peaks in the Doppler spectrum whether by smoothing or by curve fitting. Among these candidates, the most likely one is selected by combination of various thresholds and by some continuity criteria. The use of previous knowledge on the continuity of the wind velocity in time and height is essential. Various standard methods are also compared using simulated data (Lottman and Frehlich).

Special methods is proposed for the analysis of multimodal spectra typical to the system with poor height resolution (Le Foll *et al.*). An empirical orthogonal function (EOF) approach is introduced to the analysis of time-height section of wind data (Williams). It is now clear that better understanding of the nature of wind field leads to better estimation of spectral parameters. This approach may also be used to select windows to remove outliers in the Doppler velocity estimates.

5 Objective clutter rejection

Understanding the nature of clutters is another key for better estimation of the desired atmospheric echoes. Definition of the outliers is examined through various tests to obtain optimum rejection of outliers (Palo *et al.*). Objective methods are developed to reject air plane echoes (Currier *et al.*), and to detect echoes from birds (Riddle) using their characteristic spectral features.

6 Non-atmospheric echoes

MST radar echoes sometimes contain information on various phenomena other than wind and turbulence. Specific data processing schemes are developed to detect and analyze echoes from rain drops (Sato *et al.*) and meteor echoes (Cervera *et al.*). In the latter, it is found that use of only the first part of the meteor echo greatly improves the accuracy of Doppler velocity estimation.

Finally, it is proposed to use MST radar antennas for radio astronomy. (Woodman and Sarango). It is shown that the use of the widest spectral width is essential, and an efficient processing algorithm is developed to make use of the large amount of data in such a case.