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7.1A CODING SCHEMES FOR IMPROVING MST RADAR PERFORMANCE

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INTRODUCTION

The performance of an MST radar can be characterized by its system sensitivity and its range resolution. The former enables Doppler velocities to be determined even in the presence of very weak structures; the latter permits study of the fine structure within a turbulent region. Unfortunately, most radar systems are limited by the peak power they can transmit, and decreasing the pulse width in an effort to improve the range resolution leads to a decrease in system sensitivity by the same ratio.

Coding of transmitted signals has as its aim an increase in the effective radar sensitivity or range resolution without an increase in the peak transmitted power. His is accomplished by spreading the power in the frequency domain, giving better range resolution, without reducing the pulse width.

Two basic techniques are used to accomplish this frequency dispersion. The first involves using a type of pseudorandom code for the phase or amplitude within a single pulse, or within a finite sequence of pulses. This approach was discussed extensively by FARLEY (1983), and is not further treated here. The second technique is to code the frequency of the transmitted signal in some way. The various possibilities are discussed below, and are compared with the pulse-coding methods.

FREQUENCY-CODING TECHNIQUES

There are three separate ways in which radar signal transmissions can be frequency-coded: pulse chirping, FM/CW, and pulse-frequency stepping.

In pulse chirping (KLAUDER et al., 1960) the radio frequency of each transmitted radar pulse is varied linearly with time during the pulse. This produces a frequency spread approximately equal to the range of frequencies scanned, assuming that to be large compared with the reciprocal of the pulse width. A decoder is then used to regenerate a pulse of width equal to the reciprocal of the bandwidth of the received pulse, in an analogous way to the decoding of a pseudorandomly coded pulse. An application of this technique to ionospheric sounding was described by WIPPERMANN and BOWHILL (1967). They used identical ultrasonic delay lines to provide the complementary dispersions required to accomplish the pulse compression.

FM/CW radar was described in its initial form by GNANALINGAM (1954), and later by BARRY and FENWICK (1964) and by FENWICK and BARRY (1965). It has provided the basis for a highly successful commercial sweep-frequency ionosonde now in wide use. It has also been used in a tropospheric sounding radar with exceptionally high resolution (RICHTER, 1969).

The principle is to generate a linear frequency sweep in a CW transmitted signal, to detect the signal coherently and to achieve range resolution by Fourier transformation of the complex amplitude recorded. Since there is no possibility of time-domain discrimination between the radar return and the direct signal from the transmitter to the receiver, the system cannot work monostatically; its best applications have been in oblique scatter soundings of the ionosphere, or in tropospheric soundings at low altitudes (GOSSARD et al., 1978).

A third possibility is the use of a combination of pulse modulation and FM coding. Here each transmitted pulse is fixed in frequency, but is displaced in frequency from its predecessor by a fixed amount. The local oscillator for the receiver is also stepped by the same amount. Consider the fate of signals scattered from successive ranges in the atmosphere. They can be thought of as spaced by the range resolution of the original pulse. The coherently detected received signal from each scattering level is recorded as the frequency steps through the allotted bandwidth. It is then Fourier transformed from the frequency domain to the time domain to give the fine structure within the scattering volume appropriate to that particular scattering level.

Of course, this technique works only if the scattering configuration of the medium remains fixed throughout the frequency-stepping procedure. It is therefore little use for incoherent-scatter sounding. However, with the relatively long correlation times appropriate for MST radars, it has distinct advantages.

SIGNAL-TO-NOISE CONSIDERATIONS

Consider a radar which can transmit radio pulses with peak power P, pulse length L, and interpulse period I. In the unmodulated mode, its power density is about P/L. Let the noise power density (at VHF, usually sky noise) be N, and suppose that the scattering target (assumed very thin in this discussion) gives a scattered power density of AP/L. Then the signal/noise ratio is AP/NL for a single pulse.

If the integration time permissible without loss of coherence is C, the number of pulses transmitted in that time is C/I. The resulting signal/noise ratio for the unmodulated pulse is CAP/INL.

Now consider the same pulse, pseudorandom-coded into n bits. The bandwidth required has now increased from 1/L to n/L, the signal/noise ratio for a single pulse is AP/nNL, and after coherent integration for time C is CAP/InNL. Of course, the range resolution has improved by a factor of n.

Finally, consider the case where the same improvement in range resolution is sought by using a frequency-stepping technique. The number of frequency steps is n, and the time taken to complete one frequency sweep is nI. Assuming the same coherence time C for the signal, coherent integration can be performed over C/nI samples. The signal/noise ratio for a single pulse is AP/NL, as in the unmodulated case. That for the coherently integrated signal is therefore CAP/InNL, the same for the pseudorandom code with the same range resolution.

The main advantage of the pseudorandom-coded pulse and the chirped pulse is that the configuration of the scattering medium is required to be fixed only for a time equal to the pulse length. In MST radar, this is not significant. Against this must be set the following advantages of the frequency-stepping method:

1) The transmitter phase and frequency are changed only during the interpulse period. Large VHF radar transmitters can cause problems when phase-coded, as discussed by HERRINGTON and BOWHILL (1983).
2) With frequency stepping, only the rf stages of the receivers need to be widened to accommodate the increased bandwidth.
3) The range-sidelobe problem of a pseudorandomly coded signal is avoided.

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REFERENCES

Barry, G. H. and R. B. Fenwick (1965), Extraterrestrial and ionospheric sounding with synthesized frequency sweeps, Hewlett-Packard J., 16, No. 11, July.

Fenwick, R. B. and G. H. Barry (1964), Generation of frequency-sweep waveforms by direct synthesis, Tech. Rep. 99, Stanford Electronics Labs., Stanford, CA.

Gossard, E. E., R. B. Chadwick, K. P. Moran, R. G. Strauch, G. E. Morrison and W. C. Campbell (1978), Observation of winds in the clear air using an FM-CW Doppler radar, Radio Sci., 13, 285-289.

Farley, D. T. (1983), Pulse compression using binary phase codes, Handbook for MAP, Vol. 9, SCOSTEP Secretariat, Dep. Elec. Eng., Univ. IL, Urbana, 410-414.

Gnanalingam, S. (1954), An apparatus for the detection of weak ionospheric echoes, Proc. Inst. Elect. Engrs., 101 (III), 243-248.

Herrington, L. J., Jr. and S. A. Bowhill (1983), Phase modulating the Urbana radar, Aeron. Rep. 109, Aeron. Lab., Dep. Elec. Eng., Univ. IL, Urbana.

Klauder, J. R., A. C. Price, S. Darlington and W. J. Albersheim (1960), The theory and design of chirp radars, Bell System Tech. J., 39, 745-808.

Richter, J. H. (1969), High resolution tropospheric radar sounding, Radio Sci., 4, 1261-1268.

Wippermann, D. R. and S. A. Bowhill (1967), The application of pulse compression techniques to ionospheric sounding, Aeron. Rep. 16, Aeron. Lab., Dep. Elec. Eng., Univ. IL, Urbana.