6.2C DECODERS FOR MST RADARS

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INTRODUCTION

Different coding schemes, their advantages, and the need for the use of phase coded pulses is discussed by Farley (page 410, this volume). Here we shall limit ourselves to describe decoding techniques and equipment which has been used by MST radars and briefly present some recommendations for new systems.

Decoding can be done either by software in special-purpose (array processors, etc.) or general-purpose computers or in specially designed digital decoders.

SOFTWARE DECODING

Decoding, if done in a straightforward manner, would normally take several tens of operations per sec and would be out of the possibilities of moderately priced computers. Decoding is used to obtain optimum resolution, which in the case of MST radars is of the order of a few hundred meters, this corresponds to one complex sample per one or few μsec. If we take a 32 baud code with a baud-width of 1 μsec, as an example, straight decoding would take 64 adding or subtracting operations per μsec; certainly a requirement beyond the capabilities of even the fastest computers and a very demanding one even for specially built digital equipment. Fortunately, MST radars at VHF and lower UHF frequencies produce highly redundant information. Correlation times in the medium, and hence of the echo signals they produce, are of the order of a fraction of a second (≈ 0.5 to 2 sec for 50 MHz). This calls for coherent integration from pulse to pulse, which, when performed, reduces the amount of information by as much as two orders of magnitude.

Decoding and coherent integration are linear operations and, as pointed out by WOODMAN et al. (1980), they commute. One can perform the coherent integration first, and decode afterwards, with identical results. This possibility permits performing decoding operations in just about any mini- or micro-computer available in the market.

Coherent integration is so efficient in reducing the amount of information, that this can be put in a few tapes per day of observation. In this case, decoding, statistical processing and parameter estimation can then be performed off-line. This approach has been taken for the SOUSY radar -- using a hardware integrator -- (SCHMIDT et al., 1979) and by the same group at Arecibo with a portable 50-MHz transmitter.

Coherent integration usually requires special-purpose digital equipment, but can be done with fast array processors when used at the front end of the processing system. The M-mode at Millstone Hill uses this approach using an AP-120B for the integration and decoding (see p. 509, this volume, by Rastogi).

Jicamarca, at present, performs low resolution decoding off-line, by coherently integrating on line with a Harris/6 general-purpose computer.

HARDWARE DECODERS

Coherent integration by general-purpose computers, usually takes most of the computer power to perform this task, leaving no CPU time to perform the decoding and statistical processing. Therefore, is highly recommended to perform the coherent integration in a dedicated device. A device constructed to do this task can perform the decoding operation with very little added complexity.

A coherent integrator and decoder has been designed and built for the SOUSY radar (WOODMAN et al., 1980). To the author's knowledge, it is the only device specially designed for MST applications which has been built for this purpose. The device is described in some detailed in the cited reference. Here we shall limit ourselves to reproduce the block diagram (Figure 1) and discuss some of its features.

The W.K.R. decoder is a programmable device. It also performs the function of a radar controller. All the parameters which control the radar and data-taking sequence are programmed in 4 computer-addressable PROMS. The parameters include: transmitter IPP, baud length, code length, code sequence, sampling rate and groupings. For this purpose it interprets 16 program instructions which are accompanied by a number that specifies a time delay before next instruction is executed. Maximum sampling rate is 0.5 μsec, it can process 1024 altitudes (before decoding) with single codes, or 512 in the case of code pairs, like complementary codes.

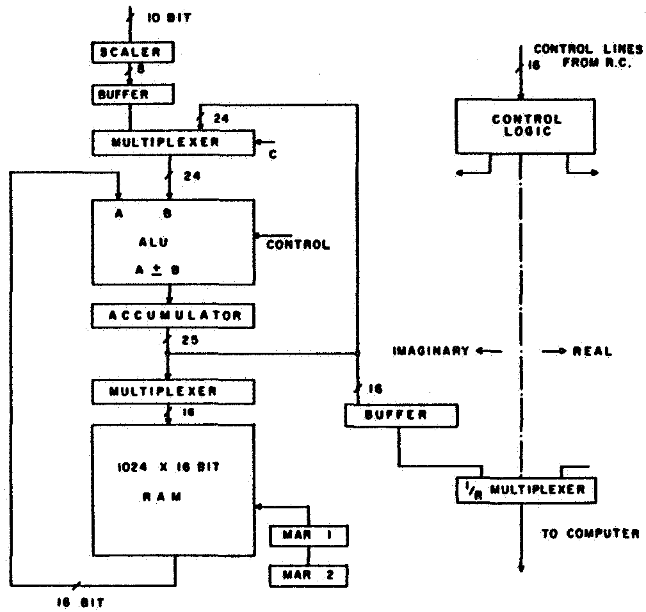
Apart of the W.K.R. decoder, the only other hardware decoder that has been used for an MST radar is the Arecibo Planetary Decoder (schematic and some text in a maintenance document at the Arecibo Observatory). The device was built for planetary radar, a more demanding application. It is capable of performing 1000 additions or subtractions per μsec and has a maximum sampling rate of 1 μsec. It has been used for decoding at the front end of any previous processing, since it has sufficient computing power to perform decoding (as much as 256 x 1 μsec bauds) without any previous coherent integration.

The device is more powerful than required by MST applications, but it was already available. It has been used to decode and coherently integrate (in that order) 32 baud complementary code sequences in conjunction with the 430-MHz radar (WOODMAN, 1980b). Its speed allows the implementation of quasi-complementary sequences. These are long sequences of transmitter pulses, each coded with a different code which present advantages that have been discussed by SULZER and WOODMAN (unpublished manuscript, 1981) but which do not permit coherent integration before decoding.

The Arecibo Planetary Decoder consists, essentially, of four parallel cross correlators. Each cross correlator consists of a selectable number of lag-product integrators (2048 maximum). Each integrator register is associated with a given lag, and integrates the product of the present, 10-bit digitized analog signal, "multiplied" by the delayed value of a 2-bit (3 level, also called 1 1/2 bits sample of the other signal (code in our case). The delay for the delayed signal is produced by a 2-bit shift register. Each integrator is associated with one of the registers of the shift register and, therefore, to a given lag delay. The necessary multiplications and updating additions are performed by 64 parallel adders per cross correlator. Speed is achieved by parallel operations and by the fact that multiplying by 3 level signals involve only additions, subtractions and no-operations (1,-1,0).

DECODING OF BISTATIC RADARS

Decoding of bistatic radars -- where the atmosphere is illuminated by a continuous, but coded, wave -- requires special discussion. The length of the code in this case is much larger than in the case of a pulsed radar. It has to be at least as long as the range of altitudes one expects to receive echoes, to prevent range folding of the echoes. This can put demands on the decoding a)



b)

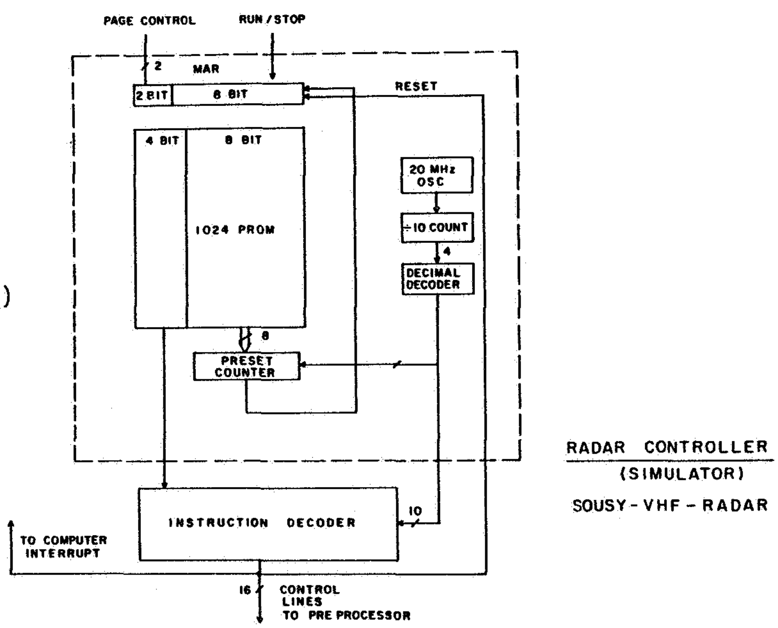


Figure 1. a. Integrator-decoder preprocessor block diagram.
b. Radar-controller and instruction-decoder block diagram.

operation which are many orders of magnitude higher than in pulsed MST radars.

So far, the only ST radar which works in a bistatic coded mode is the Arecibo 2380-MHz radar (WOODMAN, 1980a). In this case pseudo-random phase coded sequences with a baud length of 0.2 μsec and a period of 1024 bauds were used. This corresponds to a resolution of 30 meters with a range ambiguity of ∿ 30 km. Decoding at all ranges would involve ≈ 5000 operations per μsec, a formidable requirement, even when we reduce the number of ranges. Coherent integration does not help much in this case since the coherent time at 2380 MHz is nearly two orders of magnitude shorter than at 50 MHz. Nevertheless, decoding of these signals was accomplished by means of the Arecibo 1008-channel correlator (HAGEN, 1972).

Decoding becomes possible, because of the time stationarity of the radar returns, since the codes have constant amplitude and are transmitted continuously. This time stationarity permits the use of one-bit and three level (1 1/2 bit) cross correlators, which can be economically implemented by parallel integrations with a large numbers of lags at a high sampling rate. The Arecibo correlator has 1008 lags and a maximum sampling rate of 20 MHz. This represents 20,000 operations per μsec, which in this case involve simply the counting up or down of 1008 parallel counters.

The correlator at Arecibo was built for the spectral analysis of broadband (10 MHz) radio astronomy signals, by evaluating its autocorrelation function. It is divided in four identical units of 252 lags each. The scheme reported by WOODMAN (1980b) used two of them in parallel, one for the real and one for the imaginary, with 252 lags on each. This limits the range of observations to 7 1/2 kms, which is more than enough, since the range of altitudes of interest is from ≈ 14 to 19 km. The radar can illuminate below 14 km and there is no sensitivity beyond 19 km.

The Arecibo correlator has one limitation: it takes too long to dump the information. It takes so long that two consecutive decoded profiles do not have any correlation in between. This lack of correlation did not allow the determination of either the velocity or spectral width of the echoes. This limitation has been circumvented recently by using the other half of the correlator in what corresponds to a double scheme.

At present a new correlator is being built at Arecibo, which will have a buffered dump, with practically no dumping delay between decoded profiles. This should allow the evaluation of full spectral information in the future.

CONCLUSIONS AND RECOMMENDATIONS

MST radars should include hardware coherent integrators. This reduces the decoding efforts by many orders of magnitude. Once the decision to include a hardware coherent integrator has been made, a decoding operation can be included with little additional money and effort. If coherent integration and decoding is performed with dedicated devices, the existing computing capacity can be used for statistical computations and parameter estimation.

Long sequences of codes, like the quasi-complementary sequences, cannot be implemented with simple coherent integrators and decoders. Straight decoders are required, but devices simpler than the Arecibo decoder would have to be implemented for these codes to be economical.

Bistatic CW radars should use continuous periodic pseudo-random codes. One-bit correlators can perform the decoding operation economically.

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