NOISE ENCOUNTERED IN RADAR—METHODS OF REDUCTION

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ABSTRACT

The different types of noise encountered in a radar such as clutter, receiver noise, cosmic noise, are described. The various devices which are employed for minimising the effect of these noises such as logarithmic amplifiers, FTC, parametric amplifiers and masers, are discussed. Mention also is made of methods for reduction of noise based on information theory. It is concluded that by a judicious application of some of these methods, it may be possible to increase the effective range of a radar.

Introduction

It is well known that in radar, signals reflected from such objects as the earth's surface, the surface of the sea and the reflections from rain and such other undesirable objects appear in the display scopes as a noise known as 'clutter'. It is also known from the theoretical study of Bernstein[1] and Swerling[2] and from the computations of Murty and Murthy[3], that there is a limitation on the accurate determination of the azimuth angle of a target in any search radar, on account of the presence of receiver noise and the fluctuations of the target cross-section. In addition, there is the noise from the extra-terrestrial sources known as 'cosmic noise'. Various attemps ([4, 5, 6, 7]) have been made to minimise the effect of above mentioned limitations on the performance of the radar. Mention may be made of the development and use of system known as the instantaneous gain control, sensitivity time control, use of logrithmic devices and use of circular polarisation for the reduction in clutter. In addition, various types of filtering net-works[8] have been developed for the reduction in the receiver noise such as matched filtering, comb filtering[9], linear integration and correlation. Further the development of the moving target indicator system[10] reduces to a very great extent signals other than those from the desirable target to be reproduced on the scopes.

The object of the present paper is to describe the characteristics of the various types of noises mentioned above with a critical discussion of the different techniques, developments for the minimization of respective effects.

Nature of noises

(*i*) *Clutter* [10, 11]—Clutter is a type of noise which can be statistically predicted over a number of consecutive pulses. Targets responsible for ground clutter include motionless objects like tree trunk, rocks etc. and such assemblies consisting of leaves, branches, etc. which move in the wind. Sea reflections usually cover a considerable area which contain a very large number of small echoes each of which changes in position and brightness from one revolution of the radar scanner to the next. The fronts of the waves give stronger echoes than the backs and therefore the clutter area will not be symmetrical about the ship. A choppy sea produces closely spaced returns which may be so dense nearer the centre of the screen as to give the effect of an almost solid echo. If the movement of the sea is largely due to swell, there will be a wider space between the echoes although they will extend to some distance. The strength of the rain clutter depends upon the intensity of the storm, that is, upon the size of the drops and the spacing between them.

(*ii*) *Receiver noise*[10]—The receiver noise is mainly contributed by the converter, local oscillator and the IF amplifier of the radar receiver, the noise contributions being independent of each other. The overall noise figure of the receiver system is very much influenced by the conversion gain of the converter and the effective temperature of its IF resistance viewed at the IF terminals of the mixer. This crystal noise according to Weisskopf[12] comprises of (*a*) thermal noise of the spreading (semi-conductor) resistance, (*b*) shot noise caused by electrons flying over the barrier (c) fluctuation noise caused by motion of charges on the contact surface. According to Pierce[13], the local oscillator noise is composed of (*a*) shot and partition noise in electron beam coupled out through the cavity, (*b*) amplitude modulation of the oscillator by IF noise components in the beam, (*c*) frequency modulation of the oscillator at the I/F rates cause by the fluctuation in the phase of the returning electrons. The receiver noise phenomena is random in nature. Coupled with the fluctuations of the target cross-section, the receiver noise imposes a limitation on the accurate determination of the position of target in any radar.

(*iii*) *Cosmic noise and other noises*[10]—The thermal radiation from the inter-steller bodies is intercepted by the highly directive antenna employed in the radar system. At microwave frequencies. thermal radiation omitted by the surrounding objects as well radiation from the objectives upon which the antenna is pointed are picked up by the antenna. This type of noise is called 'antenna noise.'

Methods of reduction of the noises

(*i*) *Reduction of Clutter*—Several techniques have been developed for the reduction of clutter saturation such as reduction of receiver gain, IAGC, STC, logarithmic amplifier, FTC and circular polarisation. By reducing the receiver sensitivity, the strength of clutter is decreased but at the same time, weak signals are lost. An improvement in the system of gain reduction is the sensitivity time control. The gain of the receiver, in STC, is reduced to minimum after every transmitted pulse and then gradually raised to the maximum sensitivity at a rate determined by practical considerations, particular to the explored area, thereby reducing the saturation possibilities from close permanent echoes. The STC control has proved to be successful in operation with sea return but not generally useful in rain storm clutter where the clutter pattern is not uniform and as it requires considerable skill in adjustment. In civil marine radars, the linear receiver is followed by a differentiating or fast time constant circuit (FTC), the time constant being nearly equal to the reciprocal of the pulse-length, to reduce the intensity of the clutter background and enables large targets to be seen in it. A further improvement is the instantaneous automatic gain control system (IAGC). Here the receiver sensitivity is normally kept at maximum and when an echo strength rises above a predetermined level, the sensitivity is automatically reduced, corresponding to strength of the echo. As soon as the strong echo ends, the receiver returns to its full sensitivity with a certain recovery time. The main disadvantage in this system is its inherent time constant which disables the receiver to recover back quickly thereby losing weaker signals. A better method from practical point of view for reducing all types of clutter is to use an IF amplifier with logarithmic input-output characteristics. This method combines the advantages of all the above-mentioned systems such as absence of saturation even from close permanent echoes as in the STC system, a sense of clutter fluctuations at the output unlike the IAGC system and a shorter recovery time to full sensitivity than in the IAGC system without its practical disadvantages. Rain clutter is reduced to a considerable extent by the use of "circular polarised radiation".[14] The above mentioned methods when used properly and in suitable combination produce good results in the reduction of all types of clutter.

(*ii*) *Reduction of receiver noise*—Noise normally present in the receiver, can be reduced by circuit ingenuity and improved methods of construction and use of lower temperatures. Filtering techniques such as matched filtering, comb-filtering, linear integration and correlation etc. which admit only that noise which is coincident with the spectral components of the signal but not the noise which lies outside the signal spectrum, are useful devices in reducing the receiver noise. The matched filter is composed of tapped delay lines, weighting amplifiers and an adding bus. This is designed for the particular pulse width and has a frequency transfer function which resembles the spectrum of input signal. The comb filter, unlike the matched filter, integrates over more than one pulse. This method is equivalent to insertion of band pass filters of infinitesmal width at the spectral lines of a repetitive signals if the band pass filters are infinitely narrow, the filter in effect operates in an infinite pulse train and the filtering is perfect. In practical applications when comb filtering is restricted to finite number of pulses, perfect operation is not possible. The advantage of the methods like integration and correlation consists in the fact that signals reinforce upon successive additions in time whereas noise both reinforces and cancels. Integration can be achieved by introducing the signal into a number of storage elements, with given delays and then summing the delayed signals. Extreme care should be taken in the design of the filters for the optimum band width as otherwise it may destroy the pulse shape.

Another method of improving the receiver noise figure is by increasing the sensitivity of the receiver by use of some kind of R. F. amplifier. This amplifier at microwaves can take the form of either a low-noise travelling wave tube, a parametric amplifier or a maser. Typical noise figures obtainable with a travelling wave tube or a parametric amplifier is of the order of 4dB. The maser while capable of giving still lower noise figures (as low as 1dB), has however the disadvantage of having to operate at liquid helium temperatures. Present trend in radar development is to make use of these devices to obtain increased radar ranges.

MTI system

A very useful method in the reduction of noises is the use of the principle of discriminating a moving target from interfering fixed objects as in the MTI system. In this technique, the received signal is combined with the local oscillator as well as a 'COHO' oscillator output energies. The 'COHO' oscillator is triggered by the RF transmitter pulse and feeds into the receiver a constant RF voltage larger than any received echo voltage. Therefore, depending upon the relative phases of the echo changes, of the coho, changes will be produced in the RF voltage and the output voltage of the IF amplifier is a function of echo amplitude as well as the phase of the echo return relative to the coho. The IF amplifier is of a non-saturating type viz logarithmic, with two output channels—one producing a conventional video signal and the other producing an exact replica of the signal, delayed in time, the delay corresponding to the reciprocal of PRF. Then the channel to channel subtraction device eliminates completely echoes from fixed objects thereby enabling echoes from only moving objects to appear at the display scopes. In spite of the stringent requirements for the stability, systems have been developed successfully in removing all types of clutter. The main disadvantage in this system is its complexity and its inability in tracking slowly moving targets.

Conclusions

The nature of the different types of noises encountered in radar have been discussed. The different methods for minimizing the effect due to various noises have been reviewed. It is concluded that much experimental work has yet to be carried out in fully developing satisfactory anticlutter devices and efficient filtering networks for reducing receiver noise.

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REFERENCES

(1) 'An analysis of angular accuracy in search radar' 1955 IRE Convention Record Part V, pages 61-68.

(2) Swerling Peter, 'Maximum angular accuracy of a pulsed search radar' 'PIRE Sept 1956 pages 1146-1155'.

(3) Murty Y. S. N. and Murthy A. N., 'Effect of receiver noise on angular accuracy of search radar' presented at the Defence Electronics Convention, 1959.

(4) Croney, J. 'Reduction of sea and rain clutter in marine radars' Journal of Inst. of Navigational Research, 175—180, 190-4 April 44.

(5) Alred R. V. & Reiss A. 'Anticlutter receiver' J.I.E.E. Nov. 1948, Vol. 95 Part III page 459.

(6) Rozenstein S. 'Design of a log. receiver' PIEE, Jan. 1955, paper No. 1733.

(7) Croney J. 'Clutter on Radar displays; reduction by use of log. receiver' Wireless Eng. Vol. 33, No. 4, 83-96, April 1956.

(8) Schwartz L.S., 'Principles of noise reduction in communication channels' AIEE transactions Vol 75, Part I, 1956 page 44.

(9) George S. F. & Zamanakas A. S. 'Comb filters for pulsed radar use' PIRE Vol. 42, 1951, page 1159.

(10) Lawson and Uhlenbeck 'Threshold Signals' Radiation Laboratory series, Vol 24, page 224.

(11) Hollis and Carter 'The use of Radar at Sea'.

(12) Weisskopf V. F. 'On the theory of noise in conductors, Semiconductors and crystal Rectifiers', NDRC 14-153, May 12, 1943.

(13) Pierce J., BTL Report MM-44-140-4. Jan 29, 1944.

(14) Bonix M., Climant M. and Fre'miot. *Ann. Telcom.* Vol. 10, 159, 1955.