AD NUMBER	
AD113545	
CLASSIFICATION CHANGES	
TO:	unclassified
FROM:	confidential
LIMITATION CHANGES	
TO:	Approved for public release, distribution unlimited
FROM:	Controlling Office: Naval Research Lab., Washington, DC.
AUTHORITY	
NRL ltr dtd 4 Aug 1998; Commanding Officer, NRL	

ATI-20644

R-C-765

NAVY DEPARTMENT - OFFICE OF NAVAL RESEARCH

NAVAL RESEARCH LABORATORY
WASHINGTON 20, D. C.

CATALOG OF ANTI-JAMMING METHODS AND DEVICES

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Prepared By
THE WORKING COMMITTEE ON ANTI-JAMMING
OF THE
JOINT COUNTERMEASURES COMMITTEE

CONFIDENTIAL COPY NO. 112

NAVY DEPARTMENT - OFFICE OF NAVAL RESEARCH

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WASHINGTON, D.C.

MISSILE CONTROL DIVISION

CATALOGUE OF ANTI-JAMMING METHODS AND DEVICES

Prepared by

The Working Committee on Anti-Jamming
of the Joint Countermeasures Committee

September, 1945

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* Published by Arrangement With
The Joint Countermeasures Committee

August, 1946

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PREFACE

To meet an urgent war-need, the "Catalog of Anti-Jamming Methods and Devices" was originated and prepared on September, 1945 by The Working Committee on Anti-Jamming of the Joint Countermeasures Committee. At the conclusion of World War II, the Working Committee became inactive shortly after submission of this "Catalog" to the Joint Countermeasures Committee. The A-J Committee in recommendations contained in the minutes of the final meeting (JX/CM 55/9 dated 15 September 1945) pointed out that "anti-jamming for each type of radio wave device be made the responsibility of the appropiate committee of the Joint Communications Board".

Numerous requests from service project engineers and contractors for radars directed to the Naval Research Laboratory have indicated the need for publication and dissemination of the "Catalog". Therefore, in response to a letter from NRL (S67-7(1131), 1100-266/46, dated 22 July 1946), publication of the Catalog by the Naval Research Laboratory was concurred in by the Joint Countermeasures Committee (Joint Chiefs of Staff, JX/CM letter to NRL, dated 21 August 1946).

The present "Catalog" (JA/R 81) has been reviewed and placed in final form for publication by the Naval Research Laboratory. Requests for copies may be directed to:

The Director
Naval Research Laboratory
Washington 20, D.C.

H.L. Flowers

FOREWORD

The military requirements of any new radar system must now take into account all types of enemy countermeasures which might be used against it. Jamming must be expected in any future operations against an enemy. In World War II, protection against enemy jamming often was sacrificed for other military requirements and in order to speed up developments and get new and improved types of radars into the field. This was justified in that the enemy countermeasures efforts did not seriously affect the operating efficiency of most of our radar equipments. This will certainly not be true in the future. Anti-jamming must take its place with range, target discrimination, accuracy, etc., as a definite military requirement.

Innumerable trick circuits and "black boxes" were developed which improved the performance of certain radars against several various types of enemy countermeasures. The information on these devices, for the most part, was highly classified and did not receive sufficiently wide dissemination among those responsible for radar research, development and production. In order to solve this problem, this catalogue was prepared. The purpose of this catalogue was to assemble in one document a brief outline of all proven anti-jamming methods. It was intended that this catalogue would serve as a handy reference for all who have need of anti-jamming information. It was not intended to provide complete information on any anti-jamming features, but merely to serve as an index. References are given on each item, which should be consulted before that item is included in any specifications for a new radar equipment.

One of the principal difficulties encountered in the inclusion of anti-jamming in a new radar is the setting up of test methods and quantitative specifications for the performance of these devices. No attempt has been made in this catalogue to do this because of the many different types and applications of radars. The performance of the anti-jamming features must necessarily depend on the characteristics of the radar in which they are included. However, test methods and performance data on the majority of anti-jamming devices included in this catalogue will be found in many of the references given. Also, it is expected that adequate specifications on anti-jamming performance can be evolved from vulnerability tests of the developmental models of new radar equipments.

It is intended that this catalogue will be kept up to date, and as new anti-jamming circuits are developed, brief descriptions and references on them will be made available to holders of this catalogue.

The Working Committee on Anti-Jamming
of the Joint Countermeasures Committee

September, 1945

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ITEM 1

General Radar Characteristics

A. Brief Description

The vulnerability of a radar to jamming will be greatly reduced if due consideration is given to anti-jamming when the general parameters of the radar are chosen. Generally, other operational requirements may dictate a compromise with the best design from an A-J point of view.

B. Benefits and Limitations

Characteristic	Benefits	Limitations
1. High Carrier Frequency	a. Considerable AJ protection because of difficulty in designing very high frequency jammers.	a. More affected by atmospherics.
	b. Effectivsness of Window greatly reduced at very high frequencies (X and K band).	b. Limited range (particularly K band).
	c. Simplifies antenna design for very narrow beams.	
2. High Peak Power	a. Increased jamming power required for effective jamming.	a. Increased size and weight of components.
	b. Increased radar performance.	b. Increased power required.
3. High Pulse Recurrence Frequency	a.* Increased jamming power required for effective jamming.	a. Limited by range requirements.
	b. More integration of pulse energy for visual discrimination on the display.	b. Sweep utilizes a greater portion of the pulse interval hence mutual interference between adjacent radars will be greater.
	c. Improved performance with some types of Doppler Devices.	

*High prf will not have as great an effect as high peak power in this regard.

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Characteristic	Benefits	Limitations
4. Short pulse length	a. Increased definition which is particularly effective against Window and other types of clutter.	a. Wide band width required in receiver increases design problems and makes application of certain backbiasing AJ circuits considerably more difficult.
5. High Antenna Gain	a. Increases the beam power hence increases the power required of a jammer for effective jamming.	a. Increases difficulty of target acquisition.
	b. Provides considerable protection against jamming when a jamming transmitter is located off angle from the target.	a. Requires larger antennas.
	c. Increases the resolution of the radar which reduces the effectiveness of Window.	
	d. Increases radar performance.	
6. Means for Changing Antenna Polarization	a. Can greatly reduce plane elliptically or circularly polarized jamming.	a. More complex antenna design.
	b. Can greatly reduce the effectiveness of certain types of Window.	

C. Recommendations:

1. The highest frequency compatible with performance requirements should always be used.
2. The highest peak power compatible with space, weight, and supply power should be used.
3. A high pulse recurrence frequency should be used. However, increased peak power will be more valuable than increased prf hence, if the duty cycle is fixed, the prf should be lowered with a corresponding increase in peak power.

4. A very short pulse length (1/4 μsec or less) is very valuable against Window, and should be used whenever possible. However, wide IF and video bandwidths are then required which make the inclusion of several other AJ circuits extremely difficult. It is recommended that two pulse lengths be available, the first very short, for use against window, and the second considerably longer (1-2 μsecs) which will require considerably narrower band receiver components and which with the proper AJ circuits should be used against transmission jamming. A single switch which will choose either pulse length and its corresponding band width will be very valuable.

5. The highest antenna gain, compatible with the operational requirements, and the size and weight of the antenna which can be tolerated, should be used.

6. Means should be provided for changing the polarization of the antenna in operation. If this is not practicable, provision shall be made to permit change of polarization as a maintenance adjustment.

D. References

1. Radiation Laboratory Report No. 72. "The Power Necessary to Jam a Microwave Radar," J. L. Lawson, dated 24 March 1943.

2. Radio Research Laboratory Report No. RRL-44. "Notes on Power Required in Noise Jamming."

3. NRL Confidential Report No. RA-3A 208A "Minimum Detectable Radar Signal and its Dependence upon Parameters of Radar Systems", A. V. Haeff.

4. Aperiodic Pulse Timing Systems Pat. Apl. Serial No. 462,525; October 19, 1942 S. C. Hight, Govt. Pat. Exch. Sheet A-1208.

5. Radiation Laboratory Report 54-28, June 3, 1943 "Slide Rule for Microwave Antennas".

6. Anti-Jamming Committee, Div. 15, N.D.R.C. Minutes of Meeting No. 9, Nov. 6, 1943.

7. Patent Application No. 563,559, filed 15 Nov. 1944, L. A. Meecham, B.T.L.; Govt. Pat. Exch., N-788.

8. RRL Report "An AJ Measure for Use Against Circularly Polarized Jamming", Division 15, No. 411-207, 20 June 1945.

ITEM 2

Frequency Dispersal

A. Brief Description

Frequency dispersal consists of scattering the frequencies of radar systems throughout the radar spectrum as widely as possible, and applies particularly to systems having the same function. This can be obtained by opening up new bands on widely different frequencies and by making each frequency band as wide as possible. In a more limited sense frequency dispersal can take the form of utilizing existing frequency bands to the limit by maximum dispersal of systems in each band and by utilizing equipments in every band for any given operation.

B. Benefits and Limitations

Benefits	Limitations
Protection against window and electronic jamming because all systems are not likely to be jammed simultaneously.	High degree of coordination of information required to fully utilize frequency dispersal. Increased maintenance and spare parts (system standardization will reduce this difficulty, i.e., SR type systems).

C. Properties

(a) Additional Requirements.

1. Flexible systems helpful (See Item 1, No. 1).
2. Careful planning of the radar situation before any operation.

Added Space	(Additional Spare parts)
Weight	None
Power	None

(b) Operational Requirements.

1. Careful planning to utilize all possibilities of frequency dispersal available.

2. Selection of magnetrons or tunable magnetrons to allow full dispersal on each band.

D. Recommendations

(a) New frequency bands should be exploited in the development of new radar systems.

(b) Old frequency bands should be exploited to the maximum by careful radar planning.

(c) Standardization progress should be utilized to simplify operation and maintenance of radar systems.

(d) The practice of setting up all equipment of a given type on one frequency should be avoided.

E. References

(a) A. J. Practices Handbook - Paper A-1.

ITEM 3

Tunability and Flexibility in Radar Systems

A. Brief Description of Systems

Tunability and flexibility in radar systems may take a variety of forms depending on the purpose of the equipment and on the complexity which can be afforded. Push-button multi-channel operation, dual-channel operation, single control frequency change, and dual or triple control frequency change are examples, with various degrees of complexity, of how tunability and flexibility may be attained. These forms of tuning may be adapted to large frequency changes or small frequency changes, again dependent on the size and complexity allowable. Broad-band antennas, broad-band plumbing, non-critical circuits, automatic frequency control, etc. are devices which aid in obtaining tunability and flexibility.

B. Benefits and Limitations

Benefits

1. Reduction in vulnerability to electronic jamming and mutual interference.
2. Can sometimes be used for lobe filling if frequency changes are automatic and rapid.

Limitations

1. Additional complexity.
2. Additional development time.
3. More weight and space.
4. Possible reduction in normal performance.

C. Properties of Tunable Systems

(a) Additional Requirements.

1. Varies from multiple transmitters, antennas and mixers to easily tunable transmitters and receivers with broad-bend plumbing.

2. More stable mechanical construction.

Added:

Space	-	0-80 cu. ft.
Weight	-	0-2000 lbs.
Power	-	0-8 kw.

(b) Remarks on operation.

1. Push button channel selection would greatly reduce the vulnerability to electronic jamming; the reduction increases with the number of channels available and the frequency spread between channels.

2. Single-control frequency change over a wide frequency band would make a system practically invulnerable to electronic jamming; over a small frequency range it would still greatly ameliorate difficulties with jamming and would allow optimum operation of receiver a-j circuits.

3. As the number of controls are increased the flexibility decreases.

4. Even an easily tunable local oscillator can greatly aid in the operation through jamming.

D. Recommendations

Every radar system should be designed with maximum flexibility and tunability (using a minimum of controls) consistant with the size, weight, purpose and operating limitations for that particular equipment. In all cases the state of the art on tunable and broad-band components should be exploited.

E. References

(a) A. J. Practices Panel Handbook - Paper A-1, A-2

(b) Development work at R.L. on microwave equipments.
Development work at NRL on meter wave equipment.
Development work at FT&R on meter wave equipment.
Development work at RCA on meter wave equipment.

ITEM 4

Shielding

A. Brief Description of Functions of Shielding

Electric and magnetic shielding is important in radar equipment in order to prevent all unwanted electromagnetic fields from affecting the receiving system. It is to be understood that filtering is a form of shielding.

Shielding is particularly important to eliminate or reduce:

1. Jamming at the intermediate frequency.

2. "Breakthrough" of radiation from nearby sources, such as radars and other electrical devices.

Shielding is also an important factor in ensuring stability of the radar set (see Item 5).

Note: The site of a radar set may be so chosen as to take advantage of the terrain to shield the radar from an undesirable interference.

B. Benefits and limitations

Benefits	Limitations
1. Protection against pick-up of unwanted signals.	1. None.

C. Properties

Additional requirements:

1. Design of the r-f section for maximum possible attenuation of undesired frequencies.

2. Minimum i-f and video cabling.

3. Liberal filtering of leads.

Remarks on operation:

None.

D. Recommendations

Although normal good design should provide shielding of sufficiently high quality, careful thought should be given to the matter of i-f pick-up, especially in sets which are known to be subject to

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such difficulties. Tests should include successful operation within an appropriately disposed field strength of approximately 1 volt per meter at the intermediate frequency.

C. References

1. RL Report No. 471, "Shielding of Microwave Receivers Against Interference at Intermediate Frequencies", Bruce Cork.

ITEM 5

Stability

A. Brief Description of Stability Requirements

Circuit stability is important in both radar transmitter and receiver. Lack of transmitter stability may result in mismatching of the antenna, make re-tuning necessary during a critical period, or cause false Doppler effects in those equipments utilizing MTI or similar devices.

It is necessary that the entire receiver, and particularly the i-f amplifier be stable. A stable local oscillator and a reasonably stable power supply are also necessary. The stability of the i-f amplifier is particularly important because jamming may increase the instability to the point of oscillation. Backbias circuits (see Item 12) should not decrease i-f amplifier circuit stability. Both erratic and periodic local oscillator frequency variations should be kept small in comparison to the IF band width.

B. Benefits and Limitations

Benefits	Limitations
1. Transmitter	
a. Maintenance of tuning and initial conditions.	a. None
b. Avoidance of false Doppler effects.	
2. Receiver	
a. Improved operation in jamming.	a. None
b. Receiver gain less dependent on jamming signal.	
c. Constant bandwidth with gain.	
3. Local Oscillator	
a. Retuning seldom required.	a. None
b. Necessary for use with optimum bandwidth circuits.	
c. An extremely stable local oscillator must be available for use with MTI.	

C. Properties

Additional Requirements:

1. Better shielding, better voltage regulation, and increased filtering. It may be necessary to use lower gain stages and extra or larger components may be needed to get adequate decoupling. All these refinements will depend on the degree of instability that can be tolerated.

D. Recommendations

It is essential that the initial design of a radar set ensures stable operation. It should be pointed out that local oscillator instability is not as serious when a well protected AFC circuit is employed. (See item 6) Tests of receiver stability should include tests with jamming signals present. Changes in termperature and humidity should have a very limited effect on circuit stability.

E. References

1. AJ Practices Panel Report: B-7 "Stability Margin" by I. H. Page.

ITEM 6

Presentation

A. Brief Description of Circuits and Functions

The most that one can accomplish in the way of AJ once the jamming has been permitted to reach the indicator is to display the information in such a way as to maximize the signal visibility in interference. Various display systems accentuate different characteristics of the signal. The principal classes used are:

1. Deflection-modulated indication (such as "A", "J", "R", etc.

2. Intensity-modulated display ("PPI", "B", etc.).

3. Aural Indication. In this type of indication a range gate is made to encompass the echo, and the audio modulation derived from the signal is made perceptible through ear-phones or other suitable indicating devices. It is useful in obtaining propeller modulation or Doppler indications.

4. Meter Displays. In this type of display a simple indicator, such as a meter, light, or bell, is actuated by the signal.

These displays can be set up and used in a variety of ways:

(a) Expanded presentation. The range and/or azimuth is expanded to permit easy signal visibility.

(b) Photographic projection. The display is photographed, rapidly developed, and projected on a screen.

(c) Flicker technique. Successive photographs or skiatron images are projected for comparison, so that movement of targets can be seen.

(d) Multicolor screens. Screens whose emitted color is dependent upon the duration of excitation are now being developed.

B. Benefits and Limitations

Benefits	Limitations
1. Deflection-modulated indication	
a. Wide effective dynamic range of presentation; hence less susceptible to jamming.	a. Not well-adapted to scanning search systems.
b. Can act as convenient test scope.	

2.	Intensity-modulated indication	
	a. Well-adapted to scanning systems.	a. Limited dynamic range.
3.	Aural indication	
	a. Can be useful in detecting moving targets in clutter, because of Doppler effects and propeller modulation.	a. Requires a "gate" on the target.
4.	Meter display	
	a. Simplest type of presentation.	a. Limited application.
		b. Easily jammed.
5.	Expanded sweep	
	a. Discrimination, which is especially helpful in clutter, Window, and the like.	a. Restricted search volume.
6.	Photographic projection	
	a. Increased time in which observer can scrutinize and judge the display.	a. Slight delay in processing and projection.
	b. Permanent record.	
	c. Advantageous for large number of observers.	
7.	Flicker Technique	
	a. Discrimination between moving targets and clutter.	a. Requires double display, with increased complexity.
	b. Otherwise, as for photographic projections.	

8. Multicolor screens

These are in experimental stage, and, at present, an evaluation cannot be made.

C. Recommendations

1. All radar sets should be provided with a deflection-modulated oscilloscope, if possible.
2. Radar sets should be provided with expanded presentation where possible.
3. The use of other techniques should depend on the character and use of particular radars.

D. References

1. Screen properties - W.B. Nottingham, RL Report No. Sec. 6-48, 1/22/42.

2. Principal development on multicolor screens at Dumont Laboratories and G. E. Research Laboratory.

3. Photographic Integration and Spread of Base Line: RCA Technical Report PTR-7C, by T. T. Eaton and Irving Wolff.

4. Flicker: Development work done in England by TRE and ADRDE.

5. Aural indication: (a) RL Report No. S-10.
(b) NRL Report No. R-2561 by A. E. Hastings.

ITEM 7

Manual Gain Control

A. Brief Description

The manual gain control is an arrangement for manually adjusting the i-f gain during operation of the radar. In the presence of jamming, overload can be largely prevented by manipulation of a properly designed gain control and the susceptibility to jamming greatly reduced.

This control can be used during normal operation to set the gain of the receiver to give optimum visibility of the target pips on the radar indicators. For strong signals it may be used to prevent overload and to increase definition. There are several types of gain control with different overload characteristics and dynamic range. It is essential to consult reference (a) for details.

B. Benefits and Limitations

Benefits

1. Alleviation of i-f and video overload.
2. Increased definition and discrimination for large signals at expense of weak signal visibility.

Limitations

1. Extent of value is limited by the speed with which the operator can properly adjust device.
2. In scanning radars, if overload is prevented in jammed sectors by gain reduction, in general the visibility of weak signals in unjammed sectors is reduced.

C. Properties of Manual Gain Control and Alternate Schemes

1. Additional Requirements:

   (a) An operator's control potentiometer.
   (b) Extra cabling, if receiver control is remote.
   (c) Decoupling networks for individual controlled stages.
   (d) Biasing voltage with small power drain.

   Added:
   Space / Weight / Power — Extra weight varying with installation but amounting to less than a pound in most cases.

2. Remarks on Operation:

   (a) Scanning limitation removed by using automatic back-bias scheme (see Item 12) but these circuits cause differentiation of the signals.

(b) If the clutter pattern is approximately the same at all azimuths, STC (see Item 15) is preferred over the manual gain control since it preserves maximum signal visibility at all ranges.

(c) In contrast to these alternate schemes, the manual control, in general, requires but little added circuit complexity.

D. Recommendations.

A manual i-f gain control should be provided because of its AJ advantages, even if not required for other reasons. It is essential that the i-f gain control have adequate range and satisfactory overload characteristics as discussed in Reference (a) below.

E. References

(a) AJ Practices Panel Report: Paper B-4, "Gain Control Applications", by R. S. O'Brien.

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ITEM 8

Automatic Frequency Control Protection

A. Brief Description of Scheme and Function

Protection of the AFC is desirable so that external signals cannot control the frequency of the local oscillator. If an external signal should detune the local oscillator, there would be a serious impairment of radar visibility, and an increased J/S ratio.

In the simplest form of AFC, the frequency difference between the local oscillator and the transmitted signal is kept constant at the intermediate frequency. This is done by means of a frequency discriminator, which furnishes correcting information either to the local oscillator or to the transmitter. Ordinarily no steps are taken to prevent external signals from taking control of the AFC circuit. Two schemes are customarily used to protect against this eventuality.

1. A gate is derived from the transmitted pulse, which sensitizes the AFC channel only while the pulse is on. Leakage power through the TR box is used for AFC. Thus external signals are virtually eliminated by either the gate or the attenuation through the "fired" TR box.

2. A small amount of transmitted signal power is coupled out from the r-f transmission line to a separate AFC crystal mixer. The attenuation through this coupling is usually more than 60 db. thus virtually eliminating external signal effects.

B. Benefits and Limitations of Scheme

Benefits	Limitations
1. Protection	None

C. Properties of Two Such Schemes

	A. Gated AFC.	B. Double Mixer
1. Additional Requirements:	1. Receiver modifications and a gating pulse. This pulse may sometimes be taken from the modulator or synchronizer. If not, it must be generated from a trigger.	1. Separate AFC Mixer and channel coupled to r-f line through appropriate attenuator. 2. Additional LO power. 3. Decoupling between the two mixers.
Added Space	20 cubic inches	20 cubic inches
Weight	1 lb.	1 lb.
Power	none	10 w d-c; 2 w a-c

2. Remarks on Operation:	1. Ease and permanence of adjustment. 2. Special attention must be paid to the elimination of spurious modes and harmonics.	1. "Hash" from transmitted signal "spike" requires special care in the design of the gating pulse and in the balance of the discriminator. 2. Special attention must be paid to the elimination of spurious modes and harmonics.

D. **Recommendations**

Device for protecting AFC should be included in all radar sets.

E. **References**

1. Gated AFC:
Development work largely done at Bell Telephone Laboratories. See, for example, BTL Report No. 145, "Automatic Tuning Control Studies".

2. Double Crystal Mixer:
Development work largely done at Radiation Laboratory.
See, for example, RL Report No. 687, "Some Automatic Frequency Control Circuits".

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ITEM 9

I-f Bandwidth Consideration

A. **Brief Description and Function**

The i-f bandwidth is the frequency interval over which an i-f amplifier has an over-all gain not more than 3 db down from maximum.

The magnitude of the i-f bandwidth used in a receiver is a factor in determining the signal-to-noise ratio, the degree of distortion experienced by the pulse during reception, and the susceptibility to jamming.

In choosing the i-f bandwidth, the objective usually is to obtain as large a ratio of signal-to-noise as possible even though the original shape of the pulse is somewhat distorted. This optimum bandwidth is obtained by using a 3 db bandwidth of about 1.3 times the reciprocal of the pulse width. In some cases, less distortion of the pulses can be tolerated and a wider i-f bandwidth must be used. Maximum skirt selectivity should be used consistent with the pulse distortion which can be tolerated.

For most forms of jamming an i-f bandwidth chosen from the preceding considerations will be satisfactory, although for particular types of jamming, a wider or narrower i-f bandwidth may give some improvement of visibility.

B. **Benefits and Limitations of Either Wider or Narrower Than Optimum I-F Bandwidth**

1. Narrower Bandwidth than Optimum

Benefits	Limitations
(a) Increased "setting-on" difficulties for jammer.	(a) Reduced signal visibility in receiver noise.
(b) May be used as filter for "off-tune" jamming.	(b) Reduced visibility in "railings" and clutter.
	(c) Reduced visibility in most forms of "on-tuned" jamming.

2. Wider Bandwidth than Optimum

Benefits	Limitations
(a) Improved visibility in "railings" and clutter.	(a) Reduced visibility in receiver noise.
(b) Improved visibility in	(b) Eases requirements

FM and clipped AM noise jamming. — on jammer frequency control.

C. Properties of Wider or Narrower Than Optimum Bandwidth

1. Additional Requirements: In general, wide i-f bandwidths require more tubes and/or circuit complexity.

D. Recommendations

It is recommended that an i-f bandwidth equal to one-to-two times the reciprocal of the radar pulse length be used. This consideration may be modified by tuning stability and pulse shaping requirements. Because of its value against clipped noise jamming and clutter, a wide bandwidth should also be considered. Whereever possible a dual bandwidth IF should be provided. Suggested bandwidth values are 1/T and 3/T.

E. References

1. A. V. Haeff, Navy Report No. 134.

2. A. M. Stone, RL Report No. 708.

3. NRL Report R-2508 "Some Fundamentals of Anti-Jam Receiver Circuits".

ITEM 10

Video Bandwidth Considerations

A. Brief Description

The video bandwidth is defined as the frequency interval over which a video amplifier has an over-all gain not more than 3 db down from the maximum.

Other considerations than AJ requirements require a good low-frequency response and hence the high-frequency 3 db point is essentially equal to the video bandwidth. The proper shaping of the video response curve is dictated by the transient response required. Note that in some cases very poor low-frequency response is intentionally introduced by an FTC (see Item 14) and here special considerations apply.

B. Design Considerations

In the presence of jamming, a large video bandwidth is desirable. Jamming which is not exactly in tune with the radar frequency beats with the pulse and much of the pulse energy is near a frequency equal to the difference between radar and jamming frequencies. If this difference is greater than the high-frequency cut-off of the video amplifier, a loss in pulse gain will result. This loss in signal response is not accompanied by a corresponding decrease in noise and hence there is a real loss in discernibility.

C. Properties of Wide Video

1. Additional Requirements:
   - (a) May require: (1) added complexity in video coupling circuits; (2) added tubes; depending on bandwidth desired.

   Added Space Weight Power
   - (a) Depends on circuit requirements.
   - (b) Added bandwidth can often be obtained simply by appropriate peaking. The amount of peaking that can be effectively used depends upon the requirements on transient response.
   - (c) Still wider bandwidths may require larger or additional tubes and power.

2. Remarks on Operation: None

D. Recommendations

It is desirable from the AJ point of view to make the high-frequency 3 db point of the video bandpass curve at least equal to the full i-f (3db) bandwidth. (When a third detector is employed it is adviseable to make the video bandwidth equal to twice the full IF bandwidth up to the third detector. (See Item 17.)

E. References

1. AJ Practices Panel Report: Paper B-3 "Video Bandwidth Considerations" J. L. Lawson, C. N. Allred, and A. L. Gardner.

2. Naval Research Laboratory Reports: (a) R-2392 "Report on Investigation of Anti-Jam Receivers for Search Radar"; (b) R-2508 "Some Fundamentals of Anti-Jam Receiver Circuits".

ITEM 11

Linearity

A. **Brief Description**

A linear receiving system is one whose output voltage is directly proportional to the input voltage. Linearity is not achieved if a square-law second detector is used, or if i-f or video overload occurs. If a square-law detector is used, the introduction of c-w jamming can increase the noise output enough to saturate the video amplifier.

B. **Benefits and Limitations**

Benefits

1. Essentially constant noise level as a function of c-w jamming input.

2. Minimization of angular errors in the presence of off-target jamming.

3. Helps prevent intensity modulated indicators from saturating or blocking out in jammed sectors.

Limitations

1. Unless very narrow beam widths are used, a linear system may be less accurate than a nonlinear system when tracking targets in the absence of jamming. This limitation can be avoided if a linear system is followed by a nonlinear video. An FTC (see Item 14) preceding the nonlinear video is necessary to protect it from the effects of c-w jamming.

C. **Properties**

In relatively low frequency fire-control radars, which employ rather wide lobes, the use of a linear detector results in somewhat less directional sensitivity than is obtained from a square-law detector, if a linear video is used. The extra directional sensitivity may be obtained by using a nonlinear video amplifier following the linear detector.

Use of video filtering to reduce the effect of jamming modulation requires additional components. Filtering arrangements will vary from a simple short time-constant coupling that is desirable for other reasons to a selection of filters occupying considerable space and adding several pounds to the weight.

D. **Recommendations**

A linear i-f amplifier and second detector are recommended for all radar equipments. A video filter, such as the FTC (see Item 14), is necessary to remove the effects of jamming as much as possible. This combination may be followed by a linear video, or if desired for sensitivity in tracking, by a nonlinear video. (Refer to Item 18)

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E. References

1. AJ Practices Panel Report: No. B-5, "Linear Vs. Square-Law Detection", by I. H. Page.

2. Additional References:

   (a) "A/J Practice for Fire-Control Radar Systems", NRL Technical Memorandum, 411-TM-87, 23 March 1944, by H. O. Anger.

   (b) "A Study of the Vulnerability of the Radars Mark 3 and Mark 4 to Enemy Electronic Countermeasures", NRL Report RA 3A 217A, 30 October 1944, by H. L. Flowers.

   (c) "A Study of the System Vulnerability of the Radar Mark 12 to Electronic Jamming", NRL Report RA 3A 220A, 1 December 1944, by L. W. Sessions and A. J. Stecca.

   (d) Naval Research Laboratory Reports:

   R-2456 "Standard Test Procedure for A-J Receivers"
   R-2507 "Development of Mark 12 Anti-Jam Receiver".
   R-2508 "Some Fundamentals of Anti-Jamming Receiver Circuits".

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ITEM 12

I-f Overload - Backbiasing

A. **Brief Description of Schemes and Functions**

Most forms of jamming and clutter are strong enough to reduce signal visibility by overloading some portion of the receiver. Video overload can be alleviated by the FTC (see Item 14) and the DBB (see Item 15). However, special precautions should be taken to protect the i-f amplifier, insofar as possible without the use of a manual gain control. Several methods, or combinations of methods should be used.

1. High level tubes in the last one or two i-f stages: e.g. 6AG7's in place of 6AC7's, etc.

2. Backbias. This is a rapid acting degenerative circuit which reduces the gain of the stages controlled as the output increases. This reduces i-f saturation and thus helps to preserve pulse gain. There are two general classes of backbias circuits, nonamplified and amplified. The latter is frequently called an instantaneous automatic gain control, IAGC. It generates a bias voltage by rectifying and amplifying the output voltage of the controlled stage or stages. The unamplified backbias circuit omits the amplifier stage.

B. **Benefits and Limitations of Various Schemes**

Benefits	Limitations
1. High Level Tubes	
a. Increased overload protection.	a. Effective only against CW, both unmodulated and modulated at a low frequency, and then only if followed by FTC.
	b. Not effective in reducing video saturation in clutter.
2. I-f Backbias	
a. Protection against i-f overload.	a. It differentiates signals, giving a false appearance of discrimination in solid land clutter (see note on FTC).
b. Under certain design conditions it may be used to protect against video saturation.	
c. Effective i-f backbias is required for optimum performance of FTC and DBB circuits.	b. Amplified backbias requires a somewhat critical design required to make a stable, effective circuit within JAN spec-

ification limits.

C. Properties of Various Schemes

		(a) High Level Tubes	(b) Unamplified Backbias	(c) Amplified Backbias
1.	Additional Requirements:	1. Larger Tubes 2. Additional i-f stability.	1. Additional i-f stages. 2. Shorter time constants can be used than with amplified backbias schemes.	1. A double triode per loop protected. 2. Switch and relay. 3. Additional i-f stability.
	Added			(each loop)
	Space	Slight	12 cubic inches	12 cubic inches
	Weight	Slight	0.5 lb.	0.5 lb.
	Power	6 watts d-c per tube.	2 w d-c; 2 w a-c.	3 w d-c; 2 w a-c.
2.	Remarks on Operation:	1. Satisfactory only against cw jamming and only if followed by FTC. 2. Not necessary if adequate backbias circuits are used.	1. Satisfactory against both CW and clutter, if followed by FTC. 2. Amplified backbias more satisfactory, especially against cloud and sea clutter. 3. Only the amplified backbias is satisfactory for use with DBB.	

D. Recommendations

I-f overload protection should be included in all ground and ship radars. It should also be included in such airborne search radars where added requirements are not a bar, particularly where visibility in sea and land clutter must be maintained.

E. References

1. AJ Practices Panel Reports: Nos. B-2, B-9-a, B-9-b, B-9-c.

2. Principal development work on 1AGC at Naval Research Laboratory and at Radiation Laboratory. See, for example, RL Report No. S-52, "Anticlutter circuits for AEW".

3. NRL Report R-2392 "Report on Investigation of Anti-Jam Receivers for Search Radar".

4. NRL Report R-2456 "Standard Test Procedure for AJ Receivers".

5. NRL Report R-2507 "Development of Mark 12 Anti-Jam Receiver".

6. NRL Report R-2508 "Some Fundamentals of Anti-Jam Receiver Circuits".

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ITEM 13

Video Filters

A. **Brief Description and Function**

Many components of the frequency spectrum of jamming can be removed by the use of filters in the video. Also, beat frequency components between the jamming and the signal which carry radar intelligence can be passed by filters which greatly suppress the jamming. Video filters may have either high pass, band pass, or low pass characteristics.

B. **Benefits and Limitations**

Benefits	Limitations
1. High Pass	
a. Elimination of low and medium frequency modulation of the jamming signal.	a. Echo distortion which results in slight range errors. For accurate ranging, range compensation must be used.
b. Very beneficial against all types of off-frequency jamming as it will pass the heterodyne components of the jamming and echo signals while rejecting the fundamental jamming signal.	b. Under certain conditions filter may ring causing multiple indications.
c. Improves resolution against clutter.	c. Loss in signal visibility when used against very high frequency modulated jamming.
d. May be of very simple design and still be effective.	d. Insertion loss in video amplifier.
	e. Loss of signal-to-noise ratio if improperly used.
2. Band Pass	
a. Against jamming modulated at both low and high frequencies, can appreciable reduce jam-to-signal ratio.	a. Greatly lowers resolution because of pulse distortion.
b. Can be effective against narrow band barrage jamming.	b. Must be variable or several different pass bands must be available to be effective.

c. More complex filter design.

d. Insertion loss in video amplifier.

3. Low Pass

a. Removes high frequency jamming modulation component.

b. May be of very simple design and still be effective.

a. Pulse distortion which slightly lowers resolution and range accuracy.

b. Insertion loss in video amplifier.

C. Properties of Video Filters

Added Requirements

1. Additional components including switching system, video delay line (for range error compensation), possibly added video stages to compensate for filter insertion loss.

2. Added space, weight, and power requirements: These are usually slight but are dependent upon specific radar characteristics and the choice and number of filters.

Remarks on Operation

1. Normally the only control is a selector switch.

2. Performance is improved through use of an echo rectifier (Item 17) and a tunable transmitter system (Item 3).

D. Recommendations

1. A high pass video filter, or FTC (Item 14) should be included in all radar equipments.

2. Additional filtering should be considered if space, weight, and operational complexity permit.

3. In order that video filters be fully effective, it is recommended that they be incorporated in a radar system having a transmitter rapidly tunable over a narrow range, an overload protected IF amplifier, and an echo rectifier.

E. References

1. "AJ Practice for Fire-Control Radar Systems", NRL Technical Memorandum, 411-TM-87, 23 March 1944, by H. O. Anger.

2. NRL conf ltr C-S67-5/RCM(398:SWF) to BuOrd, Code Re4f, Problem O-73T-C, "Type CAOS-50-AHY IF to Video Converter, Operational and

Systems Tests", dated 26 August 1944.

3. NRL Report R-2507 "Development of Mark 12 Anti-Jam Receiver".

4. NRL Report R-2508 "Some Fundamentals of Anti-Jamming Receiver Circuits".

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ITEM 14

Fast Time Constant Circuits

A. Brief Description of Scheme and Function

The fast time constant circuit, called FTC, is placed between the second detector and first video stage of a radar receiver. It consists of a differentiating circuit whose time constant is of the order of magnitude of the pulse length. This circuit is effectively a high pass filter and thus aids in removing CW, or CW modulated at low frequencies, from the succeeding video stages. It can also be used to advantage in ameliorating the effects of cloud and sea return, but operates best for this service in conjunction with other devices. (See Items 13 and 15.)

B. Benefits and Limitations of the Scheme

Benefits

1. Effective reduction of video overload in the presence of CW, unmodulated or modulated at a low frequency.

2. Improved operation in the presence of clutter and possibly Window when protected by a good i-f backbias.

Limitations

1. Loss in signal visibility is less than 1 db even when long sweeps are used.

2. Because of the differentiation, long blocks of signals are broken up. However, the relative amplitudes of individual signals are not preserved.

C. Properties of the FTC and of Alternate Scheme

Notes: 1. Since the DBB circuit is designed to perform some similar functions, see Item 15 for a discussion of the relative advantages of the two circuits.

2. Complicated differentiating circuits can be devised, but for most purposes the simple RC or LR circuits suffice.

1. Additional Requirements: 1. A switch and relay.

Added

Space	5 cubic inches
Weight	0.2 lb.
Power	1 w d-c

2. Remarks on Operation: 1. The RC circuits are superior to the LR circuits because of a shorter recovery time possible in a practical case. However, LR cir-

cuits have the advantage of lower insertion loss or sharper low frequency cut-off.

D. Recommendations

. The FTC should be included in all radar sets.

E. References

1. AJ Practices Panel Report: No. B-1-b.

2. Principal development work done at Naval Research Laboratory and Radiation Laboratory. See, for example, RL Report No. S-52, "Anticlutter Circuits for AEW".

3. NRL Report R-2392 "Report on Investigation of Anti-Jam Receivers for Search Radar".

4. NRL Report R-2508 "Some Fundamentals of Anti-Jam Receiver Circuits".

5. NRL Report R-2530 "AJ Video Filters for the Radar Mark 12 Receiver".

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ITEM 15

Special Anticlutter Circuits - 1. Detector Balanced Bias

A. Brief Description of Circuit and Function

The detector balanced bias (DBB) is a circuit which is particularly useful in conjunction with IAGC (see Item 12) for reducing the loss in radar visibility due to cloud and sea return, and which may be useful in reducing the effectiveness of Window jamming. It operates in the following way. The second detector in the receiver is biased by the DBB circuit in such a way that the average detector output remains approximately constant, regardless of input signal amplitudes. This is accomplished by rectifying the output i-f voltage, delaying and amplifying it to establish the bias voltage. The response of the receiver to discrete signals is essentially unchanged by the circuit action, while video saturation due to blocks of signals is practically eliminated.

B. Benefits and Limitations of the Scheme

Benefits

1. Improved visibility in the presence of cloud and sea return and possibly Window.

Limitations

1. Useful only in radar sets equipped with satisfactory i-f back-bias circuits.

2. Short shadows after large signals. (Not an appreciable increase over the shadows with proper IAGC alone.)

C. Properties of the DBB and of Alternate Scheme

	(a) DBB	(b) FTC
1. Additional Requirements:	1. Switch and relay. 2. Two diodes and a triode. 3. Delay line. 4. An effective i-f backbias.	1. Switch and relay. 2. An effective i-f backbias.
Added Space	30 cubic inches	5 cubic inches
Weight	1 lb.	0.2 lb.
Power	6 w d-c; 3 w a-c.	1 w d-c.

2. Remarks on Operation:

1. Better contrast on long sweeps than FTC.
2. Better performance in cloud return than FTC.

3. DBB is not as effective as FTC in the presence of c-w jamming, either unmodulated or modulated.
4. Critical adjustments of DBB are necessary to meet JAN specifications.
5. In the presence of sea clutter, the effectiveness of either of these circuits is improved when preceded by STC (Item 15-2) in addition to the required i-f backbias.
6. The simultaneous use of FTC and DBB is not recommended.
7. The DBB should not displace FTC from a receiver.

D. Recommendations

The DBB should be used in all radar sets where the clutter from sea and cloud return warrants the added complexity, but when included it should be used only in conjunction with IAGC. Its operation in the presence of sea return is improved, if STC (see Item 15-2) is available. It is not a replacement for FTC in all cases.

E. References

1. Principal development work done at Radiation Laboratory. See, for example, RL Report No. S-52, "Anticlutter Circuits for AEW".

2. Minutes Meeting No. 13 Anti-Jamming Committee of Division 15, N.D.R.C. on 5 June 1945.

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No. 15 (cont) Special Anticlutter Circuits - 2. Sensitivity Time Control.

A. Brief Description of Device and Function

The sensitivity time control (STC) circuit is useful in reducing video saturation due to sea, and possibly land, return. Considerably enhanced effectiveness is achieved by the combined use of STC with IAGC (see Item 12), followed by either FTC (see Item 14) or DBB (see Item 15-1). The STC operates in the following way: a time-dependent voltage is generated which is used to control the receiver gain. The attempt is made to choose this time dependence in such a way as to maintain the receiver gain at its most useful value at all ranges. Some STC circuits are combined with the manual gain control in such a way as to superimpose the desired STC waveform on the manual gain voltage.

B. Benefits and Limitations of the Device

Benefits

1. Improved visibility in sea, and possibly land clutter, for most presentations.

Limitations

1. Useful in reducing saturation only by that component of the clutter that is common to all azimuths; thus not generally useful in storms and Window.
2. Critical adjustments to achieve satisfactory results.
3. Misadjustments may cause impaired rather than improved visibility.

C. Properties of the STC

1. Additional Requirements:
   1. An initiating pulse, such as a trigger.
   2. Usually at least one additional tube.
   3. Switch or relay to render the STC inoperative as desired.
   4. Panel controls for waveform adjustment.

Added

Space	perhaps 50 cubic inches
Weight	perhaps 2 lbs.
Power	perhaps 2 w d-c; 2 w a-c.

2. Remarks on Operation:
   1. Applicable to nearly all radar sets.
   2. Can be added as small modification kit.

D. Recommendations

The STC should be included in all radar sets where the possible improvement in visibility through sea and land clutter warrants the added operational complexity. It should be used principally in conjunction with IAGC and either FTC or DBB.

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E. References

1. Development work done largely at Naval Research Laboratory and at Radiation Laboratory.
   See, for example, RL book "Theory and Practice of Pulsed Circuits", by Donald G. Fink; Chap. VI.
   See RL Report No. S-52, "Anticlutter Circuits for AEW".

2. Minutes Meeting No. 13 Anti-Jamming Committee of Division 15, N.D.R.C. on 5 June 1945.

ITEM 16

Moving Target Indicators

A. Brief Description of Scheme and Function

MTI, "moving target indication" is an attachment to radar sets which differentiates between targets of high and low radial velocities, in particular between aircraft and most forms of cluttef such as land, sea, storm, and Window echoes. Its operation depends on the fact that moving targets cause a change in the phase of echo pulses, and that the rate of change of this phase is proportional to the target velocity. In simplest form the transmitted pulse is sent out always in fixed phase with the carrier, and then split into two video channels. The first delays the echo a pulse repetition interval by means of an acoustic delay line. The delayed pulse is inverted in phase and added to the following pulse in the other channel. Slow moving targets do not change phase markedly from pulse to pulse and thus are virtually cancelled. Rapidly moving targets, however, do change phase from pulse to pulse sufficiently to suffer little cancellation.

B. Benefits and Limitations of the Scheme

Benefits	Limitations
1. Improved visibility of moving targets in clutter. Improvements possible are: (a) Move than 30 db for land clutter. (b) 20-30 db for normal Window. (c) 10-30 db for storm clutter. (d) Probably 10-30 db for sea clutter.	1. There are certain "blind" radial speeds (including zero) at which the target visibility is seriously reduced. This reduction may be in excess of 30 db.
	2. Average loss in visibility of aircraft at all speeds is about 3 db.
	3. Not applicable to automatic tracking sets of certain types.

C. Properties of MTI

1. Additional Requirements:	1. New nonsaturating receiver. 2. Stable local oscillator. 3. Coherent c-w carrier. 4. Acoustic delay line, amplifiers, and cancellation circuits.
Added Space	perhaps 10 cubic feet
Weight	perhaps 400 lbs.
Power	perhaps 800 watts.
2. Operation:	1. Can be prepared as a modification kit. 2. Because of pulse to pulse cancellation, even a small jitter in the

pulse repetition frequency cannot be tolerated. Thus a spark gap modulator is not satisfactory.

D. Recommendations

Serious consideration should be given to inclusion of MTI on all ground and ship radars. Airborne sets may find it profitable to use MTI when their principal function is aircraft search.

E. References

1. Development work done at Radiation Laboratory:
See, for example, RL Report No. 481, "The Detection of Moving Targets among Ground Clutter by Coherent Pulse Methods".
RL Report No. 481, "The Observation of RF Phase in Pulse Radar".
RL Report No. 562, "A Moving Target Selector Using Deflection Modulation on a Storage Mosaic".

2. Naval Research Laboratory Report R-2480, "A Survey of Anticlutter Devices for Naval Use".

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ITEM 17

Echo Rectifier

A. Brief Description of Scheme and Function

The successful operation of many A-J devices depends upon a difference in frequency or phase in the r-f frequency of the desired and undesired signals. The "beat-frequency" components of the phase difference components form the basis for intelligence. This information is, however, a distorted signal (sinusoidal) differing in appearance from the original unipole signal. The echo rectifier (or third detector) simply rectifies the two-sided video signal and, with the aid of filters, reshapes the signal to produce a unipole pulse. Specific circuitry employed are of the conventional half-wave, full-wave rectifier circuits, or simply a zero grid bias amplifier.

B. Benefits and Limitations

Benefits

1. Reforms composite heterodyne video signals to useable shape.
2. Reduces bandwidth requirements of video stages following the echo-rectifier.
3. Increases signal discrimination in presentation system under jamming conditions.
4. Allows operation of some automatic circuits.

Limitations

1. Increases pulse width of resultant signal over normal pulse with a possible reduction in normal ranging accuracy.

C. Properties of the Echo-Rectifier (or 3rd Detector)

1. Additional Requirements:
   1. Effective video filters and FTC.
   2. Separate video channel from normal.
   3. For single detector, (half wave), a single diode.
   4. For double detector (full wave), diodes and paraphase amplifier.

Added	Single Detector	Double Detector
Space	2 cubic inches	2 cubic inches
Weight	0.5 lb.	1.0 lb.

2. Remarks on Operation:
   1. Applicable to all radar sets using video filters.

2. Requires no separate control other than switch operating the separate a-j channel.

D. Recommendations

The echo rectifier is recommended for all radars employing video filters or other means which pass only the heterodyne (or difference) signal.

E. References

1. Rad. Lab. Navy Liaison Office secr. ltr. F42-5, S67-5, Ser. 00778/J dated 12 July 1944 to BuShips, Code 920-D1 "High Pass Filter with Echo Rectification".

2. NRL secr. ltr. Report S-S67-5/RCM(399F:JAW), Serial No. 5426, to BuOrd., Re4f, "Radar - Fire Control. Interim Report on Problem S-578R-S. 'Adaptation of the Type CAOS-50AEY IF to Video Converter to the Radar Mk 12'".

3. NRL Report "Some Fundamentals of Anti-Jamming Receiver Circuits".

ITEM 18

Fire Control Radar Systems

In general, most anti-jamming devices described in this catalogue can be applied to fire control radars. However, because they employ special lobing techniques and methods of presentation, such systems are more susceptible to many types of jamming. This special section discusses the various AJ design features and devices from the fire control radar point of view.

I. Antenna System

A. Brief Description of the System and Function

The antenna system of a fire control radar is designed to furnish position information in either two or four quadrants. The type of scan to be employed usually is based on the military requirements, and this in turn determines the choice of polarity, beamwidths, gain and frequency. For most systems it is desirable that the plane of polarization be fixed to avoid tracking inaccuracies resulting from frequency sensitive parts of the target as well as changes in interference pattern. Good antenna design should be used throughout so that the lobing or scanning action does not "pull" the transmitter frequency. The antenna pattern must not change with transmitter frequency. This requires the use of components having broad-band frequency characteristics.

B. Benefits and Limitations

Design	Benefits	Limitations
1. Sharp Beams	(a) High tracking accuracy and resolution. High degree of discrimination against off-target jamming and Window.	(a) Increased difficulty in target acquisition.
2. Proper compromise between ant. lobe pattern and crossover point between lobes for lobing radars.	(a) Eliminates need for non-linear element for accuracy in angle tracking. (b) Reduces requirements for extreme linear dynamic range in receiver circuits.	(a) Possible decrease in maximum range for angle tracking.
3. Variable lobing rate.	(a) Protection against "Peter" type jamming and rotating reflectors.	(a) Added size and weight, control unit and possibly rotating machinery.

4. Lobing in receive only.	(a) Assures non-detection of lobing rate by enemy.	(a) Added complexity of antenna system. (b) Added size and weight to antenna.
5. Simultaneous lobing.	(a) Lowered linear dynamic range requirements for angle tracking. (b) Protection against "Angle Jamming" such as "Peter".	(a) Requires two or more IF strips of stable phase and separate signal channels.

C. Special Recommendations

Sharp beams with steep slopes at the crossover point should be chosen for all lobe-switched radars. The use of simultaneous lobing in receive only should provide adequate a-j protection from the standpoint of antenna system design.

D. References

1. NRL Report RA 3A 222A, "Accurate Angle Tracking by Radar", dated 28 Dec 1944, by R. M. Page.
2. NRL Report RA 3A 217A, dated 30 Oct 1944, "Study of the Vulnerability of Radars Mk 3 and Mk 4 to Enemy Electronic Countermeasures".
3. NRL Report RA 3A 220A, dated 1 Dec 1944, "Study of System Vulnerability of Radar Mk 12 to Electronic Jamming".

II. Transmitter

A. Brief Description and Function

The effects of many types of jamming can be greatly reduced by a-j features in the transmitter and modulator.

B. Benefits and Limitations

Design	Benefits	Limitations
1. Tunability - single control coupled to receiver.	(a) Provides high a-j protection when used with a protected automatic frequency control receiver.	(a) None except for design difficulties providing pattern of antenna system does not change with frequency.

2. High prf (above 1000 p.p.s.)	(a) Better fire control information.	(a) None except where more than two systems at a given location cause more interference.
3. Jittered prf.	(a) Provides protection against "Leopard", "Peter", and rotating reflectors deception devices.	(a) Requires considerably more complex circuitry and additional components such as stable aperiodic range, sweep and timing circuits, etc.

C. **References**

1. NRL Report RA 3A 221A, "An Aperiodic Range Delay Circuit", dated 4 Dec 1944 by A. M. King.

2. NRL Report RA 3A 224A, dated 7 Dec 1944, "A Jitterbug Pulse Generator".

III. Receiver

The receiver of a fire control radar must have adequate incremental gain linearity.

A. **Benefits and Limitations**

Design	Benefits	Limitations
1. IF Band-pass characteristics (BW = 1.3/T to 2/T) (Steep skirts)	(a) For BW = 2/T high range accuracy for normal operation. (b) Maximum pulse energy for S/N and S/J consideration. (c) Approaches optimum a-j operation when using video filters.	(a) Difficult design for very short pulse lengths used in fire control radars.
2. Video Band-pass characteristics. (BW = 2xIF bandwidth up to echo rectifier.) (See Item 17)	(a) Provides amplication of pulse intelligence carrying "beat" components.	(a) Difficult video stage design for very short pulse lengths used in fire control radars.
3. FTC T = RC = pulse length.	(a) Functions as portion of video filter system at low jamming levels to	(a) Because of differentiation, angle errors

	reduce angle errors existing in the heterodyne filter technique. (b) Also see discussion on FTC, Item 14.	may result when tracking target slightly greater in range than another signal or block of signals (as clutter). Requires use of clipper. (b) See Item 14 on FTC.
4. Incremental gain linearity. (IF and Video.) (Linear detectors.)	(a) Provides angle accuracy during off-target jamming. (b) Provides more accuracy in normal (un-jammed condition) tracking.	(a) Less sensitivity in angle tracking.
5. Echo Rectifier (3rd Detector)	(a) Allows operation of some automatic circuits.	(a) Increased pulse width of resultant signal thereby reducing range accuracy.
6. Back-bias (IAGC Non-amplified type using cathode degeneration.) (See Item 12)	(a) Provides A-J protection of linear characteristics needed for fire control.	(a) Rate of action must be reduced so that angle information is available. This necessarily limits the utility of this device for F.C. applications.
7. MTI (Aural Aids, Visual Aids, Non-coherent systems)	(a) Improved acquisition and tracking of targets in Window and clutter.	(a) Angle information will never be reliably accurate.

B. Special Recommendations

The receiver should have linear dynamic range characteristics so that there exists less than a 10% change in pulse amplitude when CW jamming is applied from zero level to a J/S ratio of approximately 80 db. In combination with a single control of tuning of the transmitter and receiver r-f head, the above requirements can be met with a receiver having back-bias applied to the IF stages, a diode (linear) detector, video filters and an echo rectifier. At least, an aural Doppler range aid device should be provided in those radars where the transmitter frequency and prf are compatible for this device.

C. References

1. Rad. Lab. Navy Liaison Office Secr. Ltr. F42-5, S67-5, Ser. 0078/J, dated 2 July 1944 to BuShips, Code 920-D1, "High Pass Filter with Echo Rectification".

2. NRL secr. ltr. report S-S67-5/RCM(399F:JAW), Ser. No. 5426, to BuOrd., Re4f, "Radar - Fire Control-Interim Report on Problem S-578R-S, 'Adaptation of the Type CAOS-50AEY IF to Video Converter to the Radar Mk 12'".

3. NRL Report RA 3A 217A dated 30 Oct 1944, "Study of Vulnerability of Radars Mk 3 and Mk 4 to Enemy Electronic Countermeasures".

4. NRL conf. ltr C-S67-5/RCM(398:SWF) to BuOrd., Code Re4f, Problem 0-73T-C "Type CAOS-50AEY IF to Video Converter, Operational and Systems Tests", dated 26 Aug 1944.

5. COMNAVEU REPORT X-4615.

6. COMNAVEU REPORT X-5151 and references under Item IV and VI.

7. RRL Report 411-TM-87, "A-J Practice for Fire Control Radar Systems", dated 23 March 1944.

IV. Presentation

Most fire control radar systems employ two or more of the following types in combination: "A"-scan, for range; "K" or blanked-"K", for angle; "G" scan (target spot), for angle; "B" or "E" scan for range and an angle; "J" scan for range, and various meter indicators. Investigation has shown that types of indication for normal usage may be of little use under jamming conditions. "A" scan for range and blanked-"K" for angle provide greater discrimination against electronic jamming and Window (A gain of 3 db has been measured by replacing the overlapping "K" presentation by the blanked "K" type.) There is little cost for the advantages gained by providing "A" scan and blanked-"K" in addition to the intensity modulated and/or meter presentations. (See Item 6 for detailed discussion.)

V. Automatic Radar Systems

All automatic systems are vulnerable to jamming of any type whether of enemy origin or of natural causes. Because automatic circuitry cannot discriminate between desired and undesired signals appearing in the gates, completely successful A-J devices prior to the automatic components are required. However, because most A-J devices require manual manipulation, it is necessary that automatic radar systems be provided with switches to allow manual control under jamming conditions. The use of the more reliable and nearly automatic A-J devices can reduce the number of manual controls. Most A-J controls should consist of switches only (an exception in the case of transmitter tuning), and should require no "on-the-spot" adjustments to secure operation. Essentially all of the A-J devices described in sections I through IV are applicable to automatic systems because of the necessity of manual operation under jamming conditions. An additional requirement is that, in normal operation, target acquisition and smooth automatic tracking be accomplished in less than 5 seconds after release of the slew control. Anti-jamming circuits must either not interfere with the normal operation of the equipment or must be so controllable that they do not interfere with this requirement.

References

1. NRL Report RA 3A 218A, "Automatic Angle Circuits for X-Band Radar", dated 1 Dec 1944, by J. B. Trevor, Jr. and Lt. (jg) J. J. Myers.

ATSC FORM 50 (13 MAR 47)

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U.S. Office of Naval Research.

C - 3 - 4 - 4

ATI- 20644

ORIG. AGENCY NUMBER

REVISION

AUTHOR(S)

DIVISION: Electronics (3)
SECTION: Static and Interference (4)
CROSS REFERENCES: Radar - Antijamming (77002); Jamming (53608)

AMER. TITLE: Catalogue of anti-jamming methods and devices

FORG'N. TITLE:

ORIGINATING AGENCY: Office of Naval Research, Naval Research Lab., Washington, D. C.

TRANSLATION:

COUNTRY	LANGUAGE	FORG'N.CLASS	U. S.CLASS.	DATE	PAGES	ILLUS.	FEATURES
U.S.	Eng.		Confd'l	Aug'46	50		

ABSTRACT

Innumerable trick circuits and "black boxes" were developed which improved the performance of certain radars against several various types of enemy countermeasures. The purpose of this catalogue was to assemble in one document a brief outline of all proved antijamming methods. The catalogue should serve as a handy reference for all who have need for antijamming information. It is not intended to provide complete information of any antijamming features, but merely to serve as an index.

ATI No:		US Classification:	OA No:
[illegible]	20644	Conf'l	

C

TITLE: Catalog of anti-jamming methods and devices

AUTHOR(S): Joint Countermeasures Committee

OA: Office of Naval Research, Naval Research Lab., Washington, D. C.

Foreign Title:

Previously cataloged under No:

Translation No:

Subject Division: [illegible] (2)

Section: Static and Interference (4)

DEPARTMENT OF THE NAVY
NAVAL RESEARCH LABORATORY
4555 OVERLOOK AVE SW
WASHINGTON DC 20375-5320

IN REPLY REFER TO
5510
Ser 1221.1/0253

AUG 0 4 1998

Mr. Michael Ravnitzky
612 Lincoln Avenue #301
St. Paul, MN 55102

Dear Mr. Ravnitzky

Your request for a mandatory declassification review of the Naval Research Laboratory report, AD 113545, Catalogue of Anti-Jamming Methods and Devices, dated September 1945 was conducted.

The report is unclassified and approved for public release; distribution is unlimited.

Sincerely,

CHARLES ROGERS
Head, Classification Management
and Control Services Unit
By direction of
the Commanding Officer

Copy to:
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