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COMMUNICATIONS JAMMING WITH A PERIODICALLY QUENCHED OSCILLATOR

J. K. PULFER

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ABSTRACT

The possible application of a periodically quenched oscillator as a communications jammer is investigated. Results of measurements made with a typical repeater jammer are compared with those obtained by direct noise jamming. The jammers are tried against AM, single sideband, and FM communications, to determine the relative merits of the two types in each case.

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TEXT

FIGURES

COMMUNICATIONS JAMMING

WITH A PERIODICALLY QUENCHED OSCILLATOR

- J.K. Pulfer -

INTRODUCTION

In the problem of denial jamming of communications systems, a periodically quenched oscillator has some distinct advantages over a simple broadband noise source. The advantages increase rapidly as the frequency of the jammed system increases and its bandwidth is narrowed. For communications jamming at a frequency of 500 megacycles per second, there is no comparison in the usefulness of the two systems. The detailed operation of the jammer and some applications to c-w radar jamming have been discussed in a previous report[1]. Briefly the operation is as follows: A power oscillator is periodically quenched at a rate determined by the particular application, but of the order of 75 kc/s for most communications jamming. The oscillator then behaves as a superregenerative repeater when an antenna is coupled to its tank circuit. The output spectrum consists of a band of random noise when there is no input signal, and of discrete components when a signal great enough to overcome tube and circuit noise is applied to the antenna. One of the components of the output spectrum is on the same frequency as the input signal and can be phase-modulated by modulating the oscillator tank circuit frequency. When the output is re-radiated by the antenna, this component can cause jamming of the original input signal at other locations.

Some of the immediate advantages of such a jammer are as follows:

1) If the bandwidth of a conventional noise jammer is B cps determined by stability considerations and knowledge of the communication frequency, and if the actual communications bandwidth is only $\frac{B}{a}$ cps, then the jammer power may be reduced by a factor of $\frac{a}{n}$, where n is determined by the quench frequency and the bandwidth of the quenched oscillator, and is roughly equal to the total number of spectrum components in the output (2 to 20).

2) Since there is always a component of the output on the required frequency, stability is not a problem and the jammer output follows the jammed frequency automatically within the desired bandwidth.

3) Because the jammer is also behaving as a superregenerative receiver, the operator can (in theory at least) tell when the jammer is locking on the system signal, and can set the oscillator frequency for most effective operation.

JAMMER MODULATION

At the jammed receiver, the interfering signal will be on the same frequency as the direct signal, but generally will differ in phase. Probably the most effective transmission for jamming communications systems would be to make the phase difference random by frequency-modulating the jammer oscillator with noise having sufficient bandwidth to cover the information bandwidth of the system. When the oscillator frequency is changed there is an incremental phase shift of 90° for each incremental oscillator frequency shift of one quench frequency. Therefore, the peak-to-peak frequency deviation of the noise modulation should be at least 4 times the quench frequency for maximum effectiveness[1].

The amplitude distribution density of the modulating noise is also important . Uniform distribution is desirable since in that case the phase distribution is uniform, and the effect on the receiver is not a function of the "center" phase (see Fig. 1 which is a plot of "detector output vs. frequency of the jammer tank circuit"). On the other hand, if Gaussian noise is used, then the phase difference will be more probable at some values than others, and so the jammer would be more effective if it were cancelling at the peak of the distribution rather than adding. This is illustrated more clearly in Figs. 2 and 3. A uniform distribution of the modulating noise would produce a voltage variation at the detector output which would have a distribution similar to a sinusoid (see Fig. 4).

The superregenerative jammer noise would differ from direct amplified thermal noise (DINA) in that the former is constant in amplitude but random in phase, while DINA is also random in amplitude. That is to say, the quenched oscillator jammer output can be thought of as a carrier, phase-modulated with uniform noise, whereas the usual narrow-band noise source is treated as the product of a carrier, and noise having a Raleigh distribution (sometimes a different distribution if the source is an actual modulated carrier).

EXPERIMENTAL METHOD

In jamming, the case of principal interest at the detector is that for which jamming power is greater than signal power. The signal-to-noise ratio of the detector output under this condition will depend on the method of detection used. There are at least three types of importance:

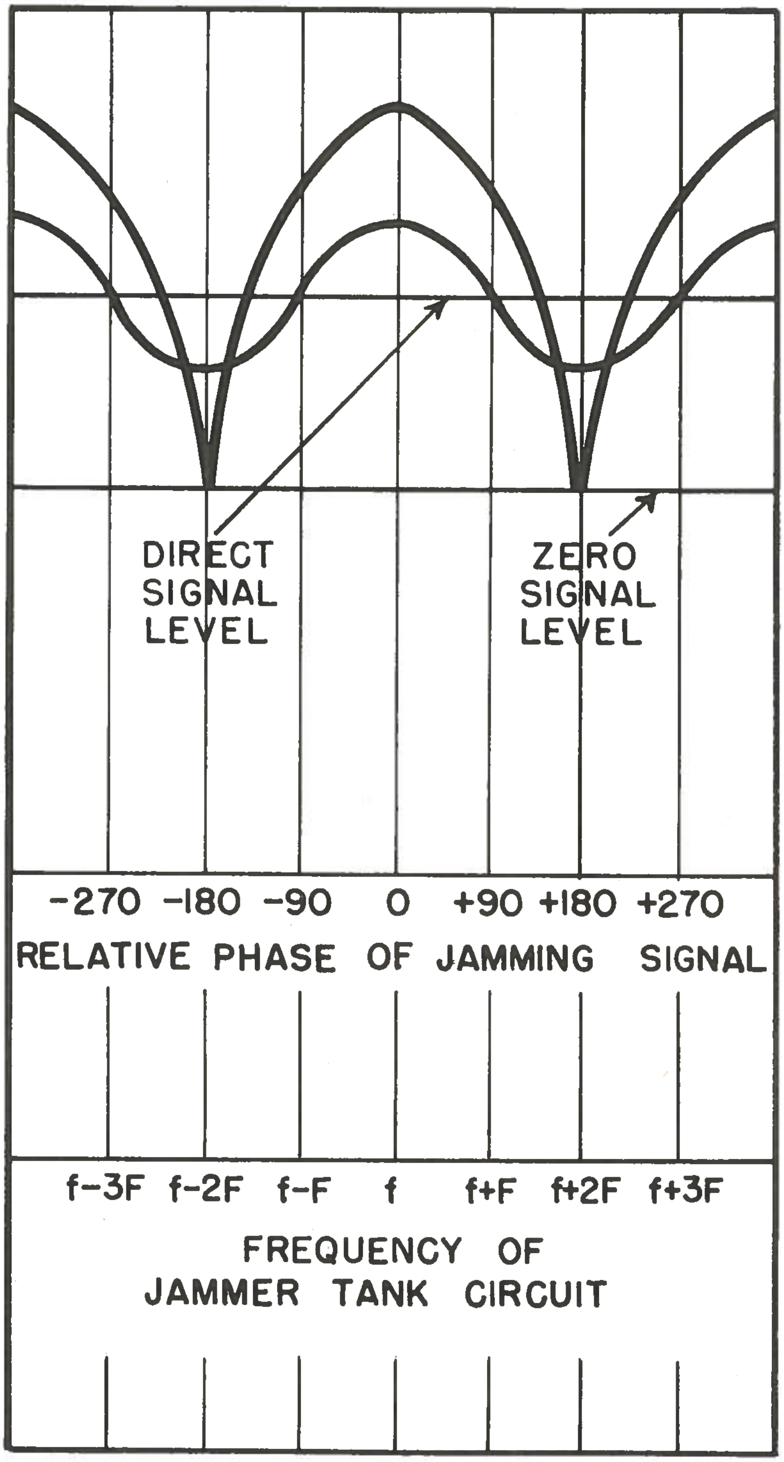

FIG. 1 DETECTOR OUTPUT vs. JAMMER TANK CIRCUIT FREQUENCY, FOR TWO JAMMING LEVELS

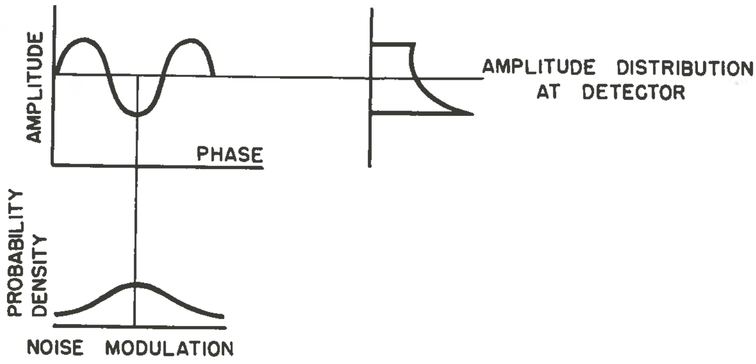

FIG. 2 "CENTER CANCEL" EFFECT WITH GAUSSIAN NOISE MODULATION

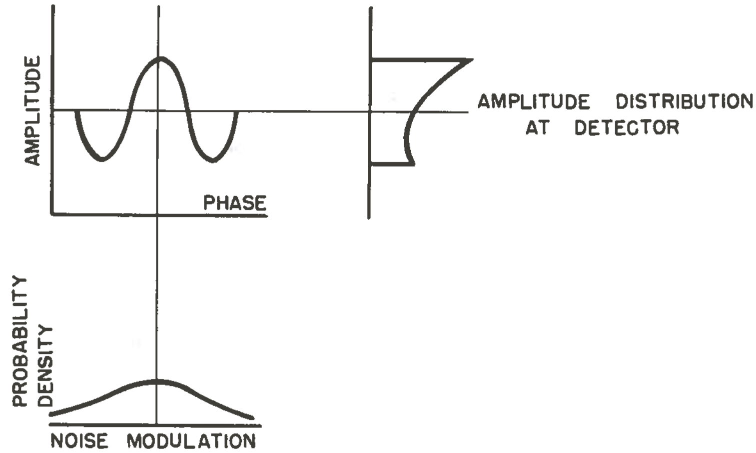

FIG. 3 "CENTER ADD" EFFECT WITH GAUSSIAN NOISE MODULATION

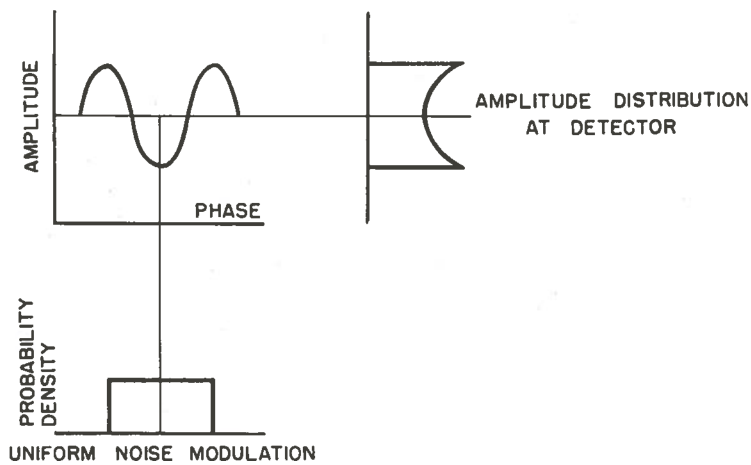

FIG. 4 OUTPUT WITH UNIFORM AMPLITUDE DISTRIBUTION ON THE MODULATING NOISE

a) The linear (or amplitude-sensitive) detector – used for AM signals.

b) The coherent (or phase-sensitive) detector – used for SSB signals.

c) The limiting (or frequency-sensitive) detector – used for FM signals.

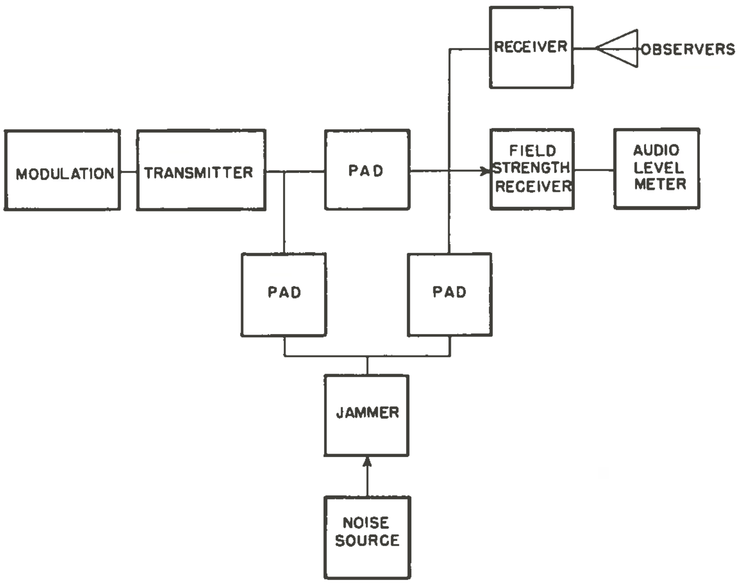

FIG. 5 EXPERIMENTAL JAMMING LAYOUT

Experimental comparison of the two types of jamming for the above three cases was carried out in the following way. The experimental setup shown in the block diagram of Fig. 5 allowed control of the signal and jamming level at the receiver. The amount of jamming power was varied, and the field strength meter reading and readability of the signal were recorded. Since readability does not easily lend itself to quantitative measurements, the results obtained were more of a subjective nature. Readability was judged as being one of the five following possibilities, and was plotted on a scale from 1 to 5 accordingly:

1) Completely unreadable – less than 1% of words understood.

2) Readable with great difficulty – approximately 30% of words understood.

3) Readable with considerable difficulty — approximately 70% of words understood.

4) Readable with practically no difficulty — only an occasional word missed.

5) Perfectly readable – 100% transfer of information.

In all three cases a band of noise covering the audio spectrum, and having approximately uniform amplitude distribution was used to modulate the jammer. The jammer deviation was chosen experimentally by listening to a receiver and setting the modulating level for maximum receiver noise output. Direct amplified noise from a type-6D4 thyratron was used as a reference for jamming. The noise bandwidth was much wider than the receiver and voltmeter bandwidth in all cases.

In order to present the results in a form which is readily understandable, the readings from the meter on the field strength receiver were expressed as jammer (J) to signal carrier (S) rms voltage ratio at the input to the detector. The methods used to calculate rms J/S from the meter readings for each type of jammer were as follows.

The readings of the field strength receiver were normalized relative to the reading when there was no jamming. For purposes of calculation, the field strength receiver consisted of a wide band filter (150kc/s) feeding an envelope detector, followed by a narrow-band filter (3kc/s) and averaging meter.

For the DINA jammer the operation of the detector was incoherent, and linear detector theory could be applied. Fig. 6 is a plot of the function relating jamming/signal power ratio into such a detector, to the normalized average output. This allowed calculation of J/S from the meter readings.

For the superregenerative jammer with uniform phase modulation, the normalized meter reading could be taken as J/S without correction. The reason for this is that for $J/S > 1$, which is the case under consideration, the presence of signal does not change the average value of J + S after the detector. That is to say average (J + S) = average (J). Further, since both J, and S, are constant-amplitude sinusoidal signals, $\frac{\text{Average } J + S}{\text{Average } S} = \frac{\text{Average } J}{\text{Average } S} =$ rms J/S.

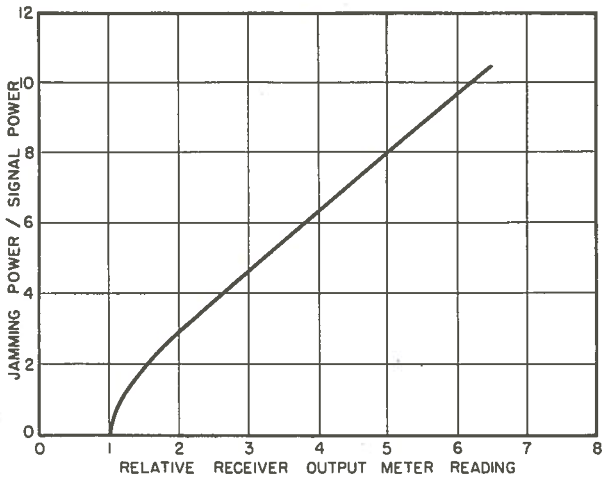

FIG. 6 CORRECTION CURVE FOR DIRECT NOISE JAMMING

For the superregenerative jammer using Gaussian phase distribution, the situation is considerably more complex. For $J/S > 1$, $J/S \cong$ normalized meter reading + $\frac{1}{2}$. That is to say, after detection, the average value of (J + S) is average (J) minus $\frac{1}{2}$ average (S), since the signal is in phase opposition to the jamming at the center of its random distribution. This approximation breaks down for values of $J/S < 1$.

The results of applying the above correction factors to the experimental data are given in Figs. 7, 8, and 9, which are plotted as "readability vs. J/S" for the three types of detectors.

DISCUSSION

The curves for the AM case are typical of what can be expected with this jammer. The power advantage of the superregenerative repeater with the bandwidths used in these measurements is of the order of 10 db for complete denial of information. For DINA 6 db has been quoted as the approximate audio jamming-to-signal ratio required for complete denial [2] and this would represent 3 db ahead of the detector. The field strength meter had a bandwidth of 150 kc/s before the detector, while the signal bandwidth was approximately 3 kc/s, resulting in an additional 17 db which would make the measured J/S for denial equal to 20 db, agreeing with experimental results (see Fig. 7). The 3 components of the jammer output separated by 75 kc/s accomplished the same result with 6 db for the center component. As there was approximately as much power in the sum of the two side components as in the center, the overall J/S was 9 db. This is in

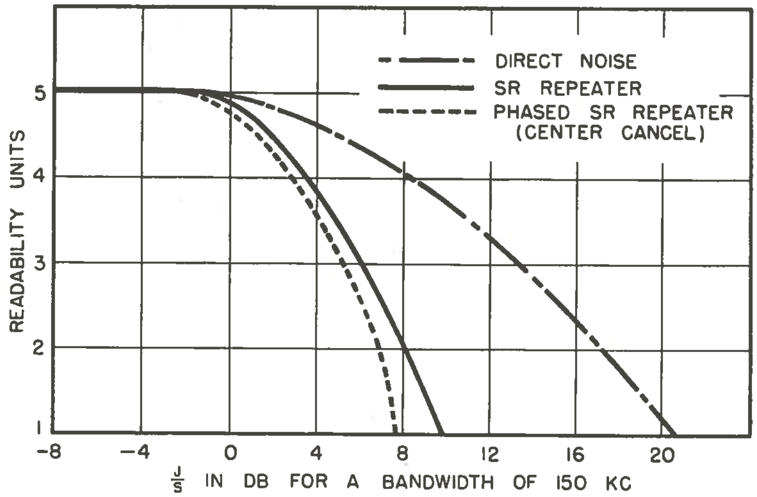

FIG. 7 READABILITY vs. J/S FOR AM COMMUNICATIONS

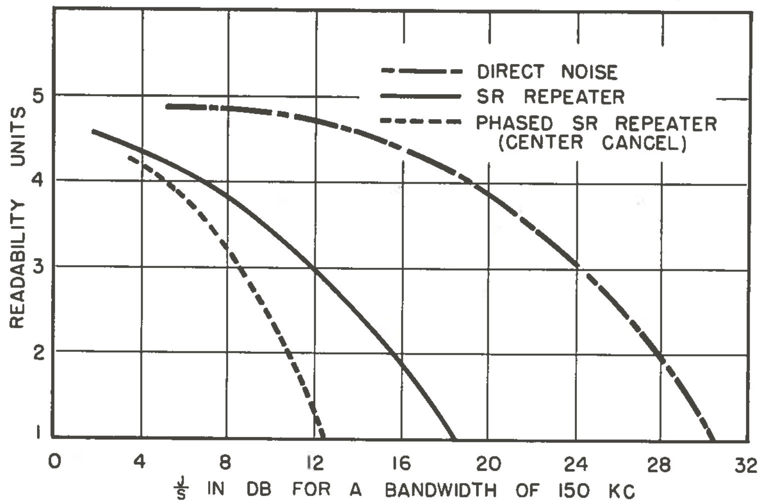

FIG. 8 READABILITY vs. J/S FOR SSB COMMUNICATIONS

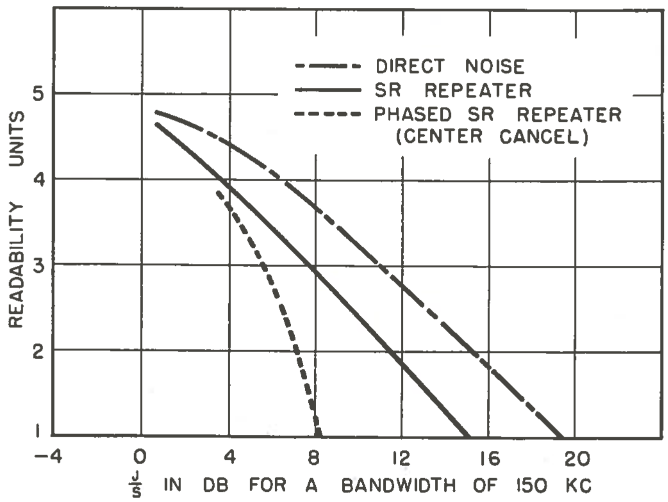

FIG. 9 READABILITY vs. J/S FOR WIDEBAND FM COMMUNICATIONS

quite good agreement with the 10 db obtained experimentally. The further improvement of 2 db in the Gaussian-modulated case cannot be obtained in practice without some knowledge of the relative phase of signal and jammer power at the receiver.

The results for the single-sideband case are nearly the same except for a 9 to 10 db increase in resistance to jamming. This can be accounted for as follows:

First, from 1/6 to 1/4 of the total power of an AM wave is in one sideband, but all the information is there, so that a gain of 6 to 8 db is realized by using only one sideband.

Secondly, the detector of the receiver operates in a coherent fashion owing to the locally injected carrier, so that 6 db J/S is required ahead of the detector to produce 6 db J/S audio, whereas in the linear case 3 db was sufficient.

This results in an overall gain of 9 to 11 db.

In the FM case, it is found that 2 to 3 db less total power is needed to jam FM than AM with DINA. This is not as large a difference as has been obtained by others (3 - 6 db) [2] but is within experimental error. The periodically quenched oscillator jammer fails to give this same gain because the FM modulation on the signal is reproduced in the jammer output so that large ratios of noise deviation/signal deviation cannot be obtained.

CONCLUSIONS

For two of the three types of communications systems investigated, appreciable gains in effectiveness can be obtained through the use of a superregenerative repeater jammer. It is felt that much more work could be done in this field to exploit these gains. This type of jamming is not satisfactory against FM communications.

ACKNOWLEDGEMENT

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