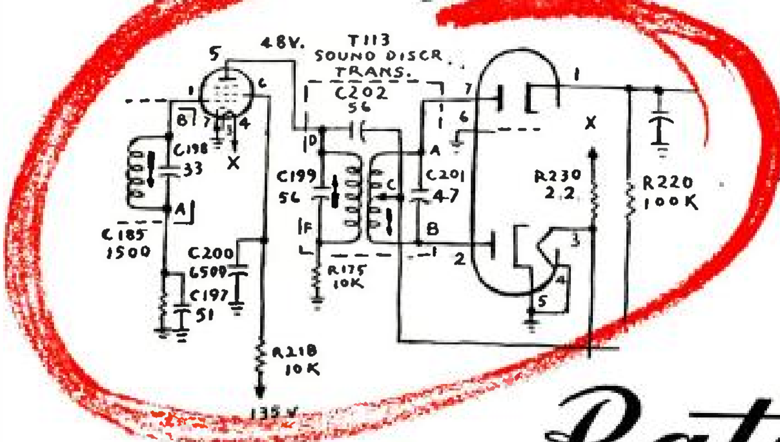
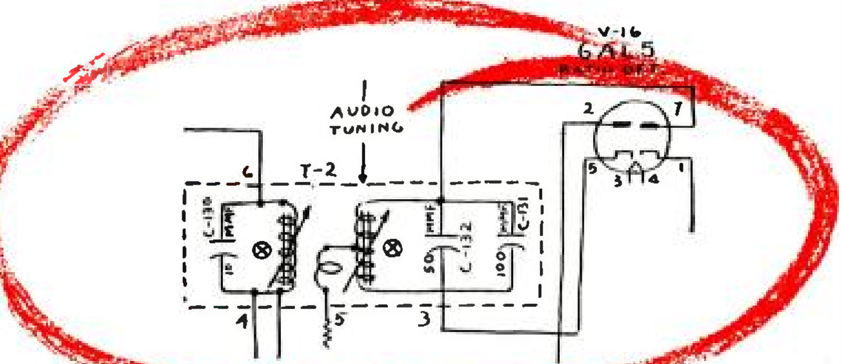
Limiter Discriminator versus Ratio Detector





By H. K. MILWARD
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In Britain there is as yet no regular FM broadcasting, and there has been no propaganda blitz over the respective merits of the limiter-discriminator and ratio-detector systems as noise rejectors. An inquiry into this question can thus be undertaken with a completely impartial approach and with no background of "political" bias. That is why the Editor asked us some months ago to make a series of comparative tests and to report the results which we obtained. Standard components made by leading firms in the United States were sent us in England and these were used in circuits made up for the tests, which were conducted in one of the best equipped radio laboratories in the country

The ratio detector is simpler than the discriminator with its necessary limiter or limiters; it requires fewer components, and, although a little more difficult to adjust in the first place, it is likely to be considerably cheaper to produce than the other. It is therefore important to know how its inherent noise rejection —one of the great advantages of FM over AM—compares with that of the limiter-discriminator. The conclusions we reached as the result of measurements and a series of aural tests are:

1. Though the difference in noise rejection is not great, the discriminator with one limiter is a slightly better performer than the ratio detector;

2. The discriminator with two limiters is decidedly superior to the ratio detector;

3. The superiority of the discriminator is most marked when the noise level is high.

In the measurements made, peak values of both signal and noise were used. Actually, the annoyance effect of impulse noise is proportional to peak values only when the recurrence of pulses is slow. As the recurrence frequency increases, the annoyance level becomes proportional to r.m.s. values[1]. For comparison of the two circuits, however, it is immaterial whether peak or r.m.s. values are used so long as the same measure is used for both.

A block diagram of the complete test circuits is shown in Fig. 1. The r.f. and first i.f. stages were part of a receiver designed for FM. The i.f. and oscillator stages were modified to give an output at 10.7 mc. Two small coils of one turn each were wound on the output transformer of this i.f. stage and the output fed *via* two short co-axial leads to the test circuits. This insured that the test circuits were fed with similar signals so that comparative tests could be made simply by switching.

The noise generator was made up from a 6-volt vibrator, a car ignition

[1] BBC Research Department, Report G.036.

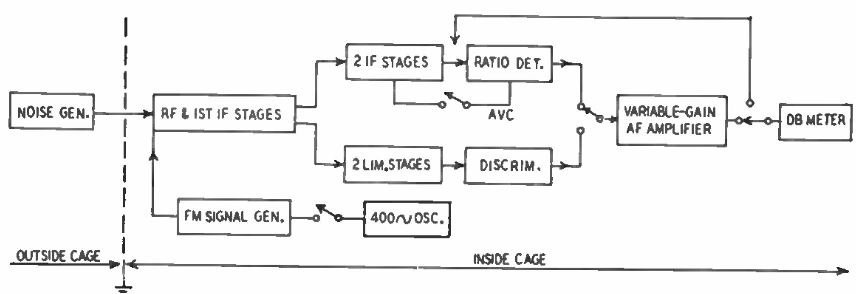


Fig. 1—Equipment used to compare ratio detector with limiter-discriminator.

coil, a spark plug, and a 6-volt storage battery. These were mounted in a double metal box as shown in Fig. 2. Originally it was intended to vary the noise signal by altering the coupling of

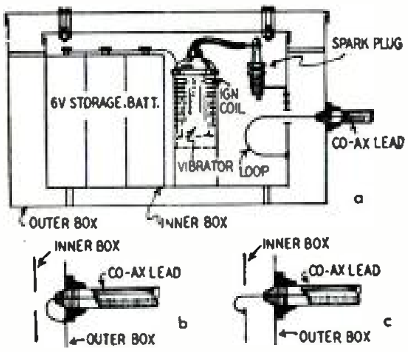


Fig. 2—Details of noise generator.

the coil feeding the receiver, but this was found unsatisfactory, for the noise signal stubbornly refused to be attenuated by more than a few db. The difficulty was overcome finally by feeding the first r.f. coil as shown in Fig. 3, and varying noise strength at its source. Three levels of noise were obtained by

1. Connecting the inner conductor of the co-axial to the outer box in a very small loop (Fig. 2-b).
2. Connecting it to the inner box in a small loop (Fig. 2-c).
3. Connecting as in Fig. 2-a with a large loop.

For the tests the noise generator was placed outside the shielded cage in which the rest of the work was done, and the co-axial led through the mesh of the cage.

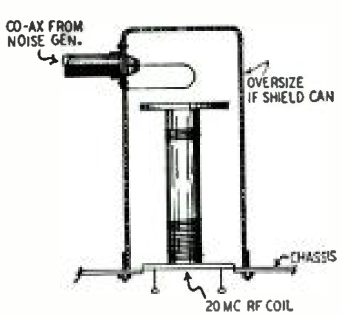


Fig. 3—Method of injecting the noise.

Some attenuation of noise level was obtained by leaving a long cable between the cage and the generator. The lowest level provided gave output signal-to-noise ratios of around 1 for signals which were just above threshold for limiter or a.v.c. action. The generator produced 50-70 noise pulses per second.

The signal generator was a simple FM oscillator which had been calibrated for the tests. The deviation it produced was not linear; but as the tests required only a signal to be compared with the noise, this was no disadvantage.

The circuits tested are shown in Figs. 4 and 5. (The schematics have been simplified by leaving out screen and suppressor connections.) They were lined up at 10.7 mc with a 160-kc bandwidth with the aid of an oscilloscope and sweep oscillator. Response curves for the two test circuits were made as similar as possible. The curves showed a response which was level to within 3 db 70 kc each side of 10.7 mc and was 6 db down at ± 80-kc deviation. The loss beyond these limits was about 0.4 db per kc.

When the i.f. stages were satisfactorily lined up, the demodulators were tackled. The discriminator gave the curve of Fig. 6-a without adjustment, and the ratio detector gave that in Fig. 6-b after adjustment of the tuning slugs in the transformer. The ratio detector was then adjusted for maximum AM rejection by injecting a 400-cycle signal into the suppressor grid of the

To assure complete impartiality, this comparative test of ratio and phase detectors was arranged in England, where regular FM broadcasting has not as yet been established.

first r.f. stage, which produced a signal which was amplitude-modulated. The presence of output containing a 400-cycle component was shown by the oscilloscope[2]. The circuit values were adjusted until this component was a minimum.

The outputs of the two demodulators were connected *via* a changeover switch to the a.f. amplifier and meter. No de-emphasis circuit was used as it would not have affected the relative merits of the circuits. The a.f. amplifier was a simple, two-stage, negative feedback combination, with an input impedance of about 20,000 ohms. The gain was controlled by varying the feedback path in fixed steps of 4 db.

The output meter was a v.t.v.m. with two inputs, one for r.f. and one for a.f.; and the meter itself was calibrated in decibels (reference 1 milliwatt). The meter input impedance was approximately 6,000 ohms, and the amplifier output impedance was adjusted to match. Thus readings of relative signal strengths could be made directly. The scale readings for a.f. signals were checked and found to be accurate. For both a.f. and r.f. inputs the meter measured peak volts for anything above 30 cycles or 30 pulses per second.

After this preliminary work the main test readings were taken. First the output meter (r.f. input) was connected to the output of the two i.f. stages of the ratio-detector circuit, and the a.v.c. was switched off. The noise generator was switched on, a reading taken, and the generator switched off again. This gave the level of noise with no signal. The signal generator was then switched on (with 400-cycle FM deviation ± 22.5 kc, representing about 30% of maximum deviation) and readings were taken for each of several generator output control settings. This gave a set of signal-to-noise ratios for the r.f. side.

Following this the output meter was connected to the a.f. side and a.v.c. switched on for the ratio detector. Readings were then taken with the signal generator operating the whole time, its output being varied as required. For each previously charted output level, a.f. readings for both detector circuits were taken of noise output with modulation off and modulation output with noise off. These readings gave output signal-to-noise ratios for each circut. The actual signal-to-noise improvement, a.f. ratio r.f. ratio, depends on a number of factors including percentage modulation (in the case about 30%), and also the accuracy of the output meter at radio frequencies. Thus the improvement ratio shown by these results is not necessarily accurate, but the comparative output figures are. The results are shown in Figs. 7-a and 7-b.

The ratio detector was then altered to the form shown in Fig. 8 and a further test made. The results (Fig.

[2] This procedure is described in full in "The Ratio Detector," by Seeley and Avins, *RCA Review*, June, 1947.

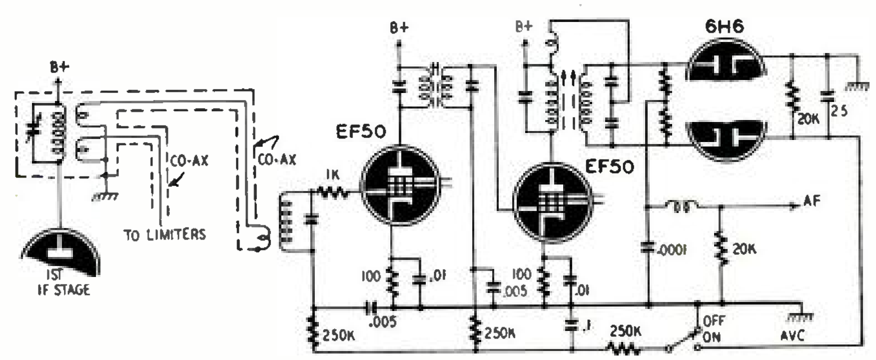


Fig. 4—Simplified circuit of the ratio detector used in the experiments.

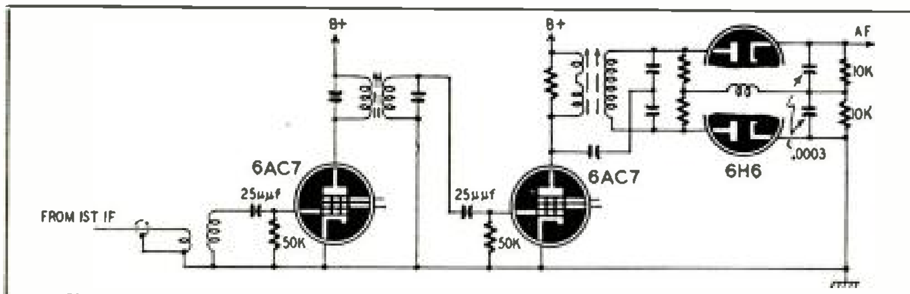
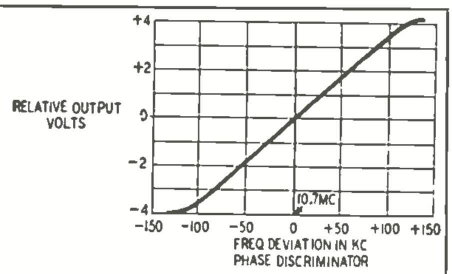
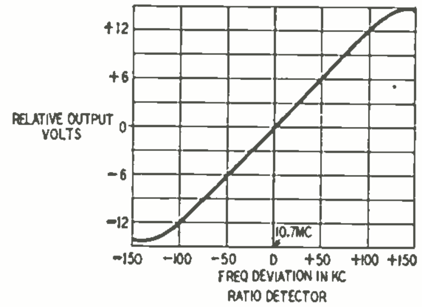


Fig. 5—The limiter-discriminator parallel of the circuit shown in Fig. 5.





Figs. 6-a, 6-b—Curves of phase discriminator and ratio detector, no noise.

7-a) are substantially the same as those for the original circuit. The results taken for two limiters with the discriminator and one limiter with the ratio detector are interesting in that they suggest a connection between noise rejection and AM rejection. This is not surprising, for a noise pulse effectively consists of two parts: that which affects only an FM system, and that which affects an AM system. There would be a certain minimum noise response from the most perfect FM system, and any practical system would be worse in proportion to its AM response.

Finally, the two circuits were tested aurally. The receiver was coupled to a short rod antenna and tuned to the BBC experimental FM transmissions. The noise generator was placed outside the building with a short length of wire protruding as an antenna. A variable attenuator was inserted in the output of the ratio-detector circuit and adjusted so that the output from a loudspeaker was the same for both circuits. Flicking the switch made it possible to compare noise levels.

In the tests four observers were asked to judge which circuit was least noisy. The ratio detector with a.v.c. and discriminator with one limiter were tried first. When the noise level was so high that all but loud passages were masked, the judgment averaged about 3 to 1 in favor of the discriminator, each observer listening to about 10 changeovers. When noise was low enough to be noticeable only during soft passages, the results were about even for the two circuits if the switching was done during loud signal passages and about 3 to 2 for the discriminator if done during the soft passages.

When the discriminator was used with two limiters, the ratio detector remaining as it was, the results were 100% for the discriminator on the loud noise test and about 7 to 1 on the low noise. These results confirmed the measurements generally, although the difference appeared to be more noticeable aurally than was to be expected from the actual figures.

During the tests both circuits stayed in adjustment and no difficulty was experienced in lining up and adjusting either. The ratio detector was somewhat more tedious to adjust, and the component values appeared to be a little more critical.

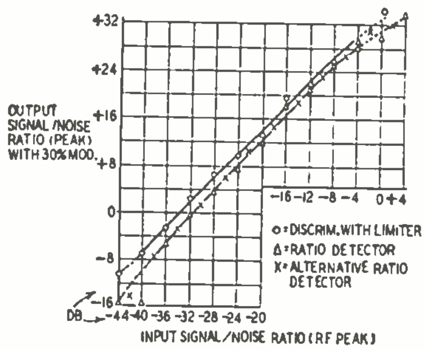


Fig. 7-a—Comparison of the two types.

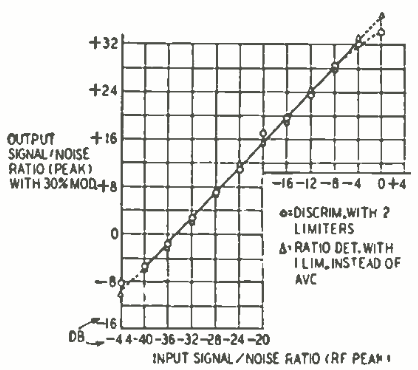


Fig. 7-b—Limiter helps ratio detector.

Thought, Memory, Produce New Brain Waves

IDENTIFICATION of a hitherto unknown brain wave, which seems to be associated with thought, is reported by a research team of the Institute for Applied Experimental Psychology, Tufts College, Medford, Mass. Readers familiar with electroencephalography will remember that previously recognized brain waves not only appear best when the mind is at rest, but are actually inhibited by thought processes.

Dips show drop in "thought output" as subject finishes reading line of type.

The four researchers, John L. Kennedy, Robert M. Gottsdanker, John C. Armstrong, and Florence Gray, have named the new manifestation "kappa waves." The figure shows how the waves appear when the subject reads. The irregular waves are produced as the reader scans each line of type, and the retrace results in the drops at S. The third and longer wave was recorded as the reader concentrated on a new paragraph. Similar graphs made while the subject was performing mental multiplications and other tasks requiring thought show a remarkable correlation of kappa bursts to periods of thought.

The kappa waves are detected by electrodes placed just back of the external canthi of the eyes (the corners of each eye where the upper and lower eyelids meet).

Later research, reported by the same workers to the recent meeting of the American Psychological Association at Denver, indicates that the kappa waves are particularly active when the brain is attempting to remember something. They reported that when a student was learning new material, kappa-wave activity was moderate. When the student was trying to recall imperfectly-learned material the kappa waves reached a maximum, and when reciting perfectly memorized matter they again sunk to a new low, the scientists reported.

Further research is being carried out on these waves, which appear to represent a new advance in brain study.

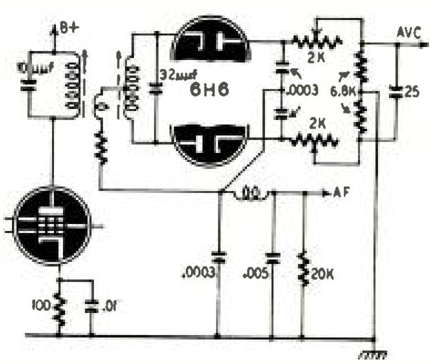


Fig. 8—An alternate ratio detector.