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ANALYZED

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NOTES ON A MEETING TO DISCUSS THE C.S.F. DIVERSITY RADAR

January 4, 1956, N.R.C.

1. A meeting was held on January 4, 1956 at the Radio and Electrical Engineering Division of N.R.C. (Building M-50, Montreal Road) to enable those present to question Mr. L.W. Hatton (DRTE-RPL), Dr. J.H. Moon (DRBHQ-D.Phys R(E)) and Mr. W.C. Brown (NRC) in regard to their observations during visits to C.S.F. in the fall of 1955. Unfortunately Mr. Brown was ill and unable to attend.

2. Present were:

F.E. Smith, DRB (EL)
R.F. Nikkel, DRB (EL)
R.C. Riordon, DRB (EL)
W.L. Hatton, DRB (RPL)
J.H. Moon, DRBHQ
F/L E.A. MacNair, DRBHQ
Lt. E.M. Byrnes, DRBHQ
H. Larnder, DRB/ORG
K.J. Radford, DRB/ORG
J. Humphries, NRC
S.G. Jones, NRC
J.R. Kenney, NRC
R.S. Richards, NRC
E.L.R. Webb, NRC
R.L. Westby, NRC
D.W.R. McKinley, NRC
R.S. Rettie, NRC

3. Mr. Hatton and Dr. Moon described their impressions of their separate visits to C.S.F. It appeared that there were three aspects to consider in detail, -first, the individual receivers, second, the effects of diversity, and third, the operations on the diversity output.

4. The Diversity Radar:- In the C.S.F. demonstrations, three transmitters were used spaced in frequency by 140 mc/s, thus using a total band of nearly 300 mc/s. The three transmitters used a single antenna and each had a receiver associated with it. The three radar systems were pulsed sequentially with a delay of about 2 microseconds between systems. These delays were compensated for in the receiver channels to bring the three received signals back into time synchronization. The display could be used to present each output, A, B, or C, at will, or the sum of the three products AB, BC, CA obtained from a correlation multiplier, or an integrated sum of these three products. This last was the form proposed by C.S.F. as the method of defeating the carcinotron by diversity radar.

5. The Demonstration Jammer:- A small carcinotron was used, placed some 200 yds. from the radar and swept over the 300 mc/s band by a sine wave sweep of 50 kc/s, -later increased to 100 kc/s. This jammer could readily be accepted as equivalent to a high power jammer much farther away. In C.S.F. tests higher frequency sweeping was used but not in the demonstration. At 50 kc/s it should be noted that the jamming signal will pass through the pass band of the receivers twice in 20 microseconds. The maximum rate of change of jammer frequency for a ±150 mc/s excursion at

50 kc/s is roughly 45 mc/s per microsecond (rates higher by a factor of 100 are not unreasonable for carcinotrons at S-band.).

6. Results Observed:- (1) The normal radar displays were completely covered with noise (no statement on grain fineness available).

(2) The correlation product cleaned up the display but left many non-persistent spots (pin-points of light).

(3) The integrated correlation product was completely cleaned up.

7. Results Quoted:- Various claims were made by C.S.F. for their diversity system. In addition to the above they claimed:-

1. No aspect fading.
2. Range increase of 25% over mean value of 3 single radars (for blip-scan ratios between 0.5 and 0.8?).
3. Max. Range up 8% (i.e., at blip-scan of, say, 0.3?).
4. (Min. Range?) (i.e., 50% blip-scan ?) up 40-50%.

Also stated by C.S.F. was an opinion that carcinotron modulated with 6 mc/s noise would reduce range 50%.

8. Discussions:- All those present at this meeting had an opportunity to question Dr. Moon and Mr. Hatton and to express their views on what was in fact taking place in the diversity radar. These notes include not only an impression of what was said but also additional information secured later from Mr. Brown, and Mr. J.W. Cox.

9. Receiver Front Ends:- It was assumed that no special action was occurring in the receiver front end beyond normally good design to avoid overloading.

10. Normal Radar Results:- The displays were described as completely lit-up. If the range displayed was 100 n. mi. on a 10" P.P.I., a spot size of 1 mm. would correspond to about 0.8 n. mi. or nearly 10 microseconds. Since the centre radar has the jammer cutting through every 10 microseconds at 50 kc/s, there the whole tube could in fact be covered due to this process alone. If the pass band were 2 mc/s wide, the jammer would pass through it in about 1/20 microsecond. The natural response time of the receiver would be greater than this and would be approximately 0.5 microseconds. This last figure would add to the spot size figure and increase the evenness of the illumination.

11. Diversity Product:- The general consensus of the meeting was that the magical clean-up of the display was in fact attributable to the specialized non-sophisticated form of jamming used. The principle employed is that the jamming signal cannot be in more than one channel simultaneously while the radar signals are in all channels effectively simultaneously. The notion of simultaneous occurrence needs clarification [illegible] reach another channel before

the natural receiver response is over in the previous channel. Even allowing for the two microsecond delays, and a natural response time of 1/2 microsecond, it is apparent that enough time is available at a 50 kc/s rate (and at 100 kc/s) for non-simultaneous jamming. Thus only one or neither term of each product included a jammer term and so all cross-products were zero (or small-jammer times set noise) as opposed to large (signal times signal) for at least one if not all three products. It was regretted that more tests were not seen using higher sweep rates (or the equivalent, as far as simultaneousness is concerned, of operating with the radar frequencies much closer together).

12. If a wider spacing of radar frequencies were employed, one carcinotron would not be able to cover all three. If the enemy then used more than one independently modulated carcinotron, the diversity radar would be of little help. No useful conclusions were reached as to the relative merits of this type of diversity, -under conditions of multiple jammers or jammers swept so fast that the interval between traversals of the pass band was approximately the natural response time of the receivers. It appeared that, in the general case, an improvement would be secured which would be slightly less than that obtained by doubling or trebling the transmitter power. Against specialized forms of jamming and by spreading the two or three radar frequencies as far as possible, much more effective reduction of noise would be obtained. Unfortunately it appears that the general case - that of very high speed swept jamming - is not unlikely to be found and so the advantages of diversity radar disappear. There remains then only the advantage that it is possible by these methods to achieve an effective increase of 3 or 5 db. in transmitter power without the need for larger tubes and modulators but merely by using more of the ones already in use.

13. <u>Integration</u>:- The storage tube TCM-12, akin to the Radechon was used. It was noted that no picture occurred on the first antenna sweep and then built up gradually. The operation of this portion of the equipment was very obscure. The vital factors of charging and discharging times of the storage element were not known. One story had these as being short, -so short that the tube acted as an adder of two successive signal trains only. This sum was then apparently compared with the second train in order to recover the first train and this in turn was multiplied with or gated by the second train so that the output contained only those signals common in time to both trains. Thus non-recurrent noise peaks were removed and this could be regarded as time-diversity.

14. A second school of thought felt that the discharge factor was long enough that many sweep or scans could be integrated. This apparently is not the case although the lack of a picture on the first antenna rotation (if true) is most confusing. This would indicate that the signal trains being compared are not those adjacent in time but those separated by one antenna sweep. This again is unlikely and so another explanation of the "first rotation effect" is needed. In passing it might be mentioned that this second school of thought was led by those familiar with Area MTI equipments and that Area MTI circuits could be readily converted to integration.

15. Note Added After Speaking to J.W. Cox (Feb. 16, 1956):- Mr. Cox is now associated with the French designer of the "noise-canceller black-box" in the SADTC lab. in Holland. He confirms that the "box" merely delays the one train and gates or multiplies (due to deliberate non-linearities) one train by its successor. The high frequency components of the noise are emphasized at the expense of the lows and are later removed by filtering. Moderately high signals are enhanced with respect to the noise, lower signals are depressed. The major advantages of diversity radar are stated to lie in the reduction of aspect fading leading to high blip-scan ratios near maximum range and in the noise-cancellation effects of the "black-box". Another advantage is "on-the-air" maintenance due to being its own "back-up".

16. The relative advantages or disadvantages of delay lines and storage tubes in an application such as this are not clear nor are the possibilities of simultaneously using a delayed pulse train noise cancelling technique and MTI, -either conventional or area.

17. These notes are being circulated for information and comments, please.

R. S. Rettie

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(Chairman vice W.C. Brown)