Notes on "Stabilotron" Symposium: held at Signal Corps Laboratories, Eatontown, N.J., April 29, 1955

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NOTES ON "STABILOTRON" SYMPOSIUM

Held at Signal Corps Laboratories

Eatontown, N.J.

April 29, 1955

S.G. Jones and P.A. Redhead

OTTAWA

May 1955

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NOTES ON STABILOTRON SYMPOSIUM

Under the auspices of the Signal Corps Electronic Laboratories a symposium was held to disclose the principles of operation and discuss applications of a new type of microwave tube which has been developed by the Raytheon Mfg. Co. The basic tube, a broad-band, saturated, backward wave amplifier, is called the "Platinotron". Two other names have been coined for the tube. When used as an amplifier it is referred to as an "Amplitron", and when used with a frequency stabilizing device external to the tube, the whole apparatus is called the "Stabilotron".

The Platinotron uses crossed magnetic and electric fields, and as such is similar in some respects to the multi-cavity magnetron and "M" carcinotron. A simplified description is that it is similar to a vane-type strapped magnetron in which the straps have been cut between two of the vanes, and are brought out to two matched terminations. A signal impressed across the termination which would transmit this signal in a direction opposite to the velocity of electron stream is found to be amplified up to 50 times in power at the other termination. As can be seen from the characteristic shown in Figure I, a certain minimum input is required if the input is to control the output.

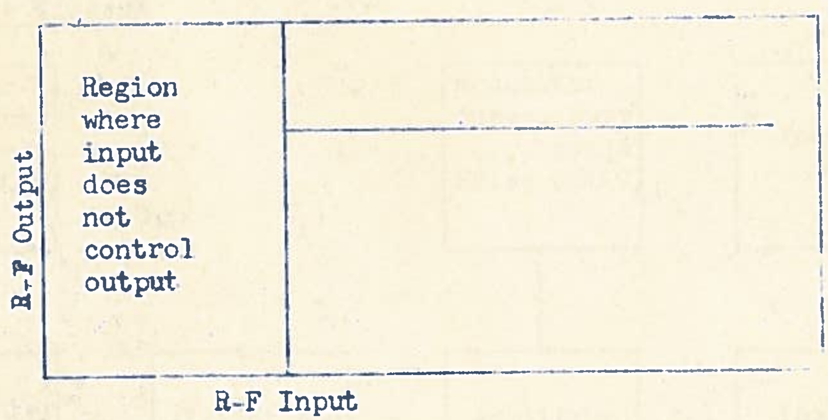
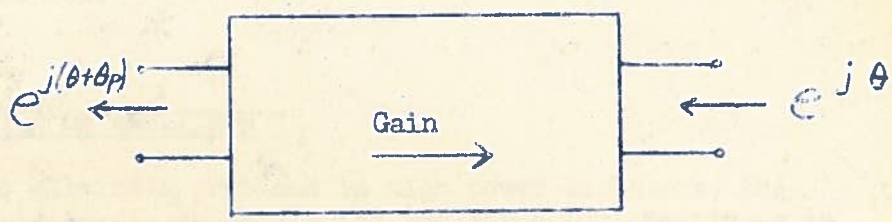


FIGURE I

The bandwidth of the device is of the order of 8 to 10%, limited primarily by the range over which sufficiently well matched terminations can be constructed.

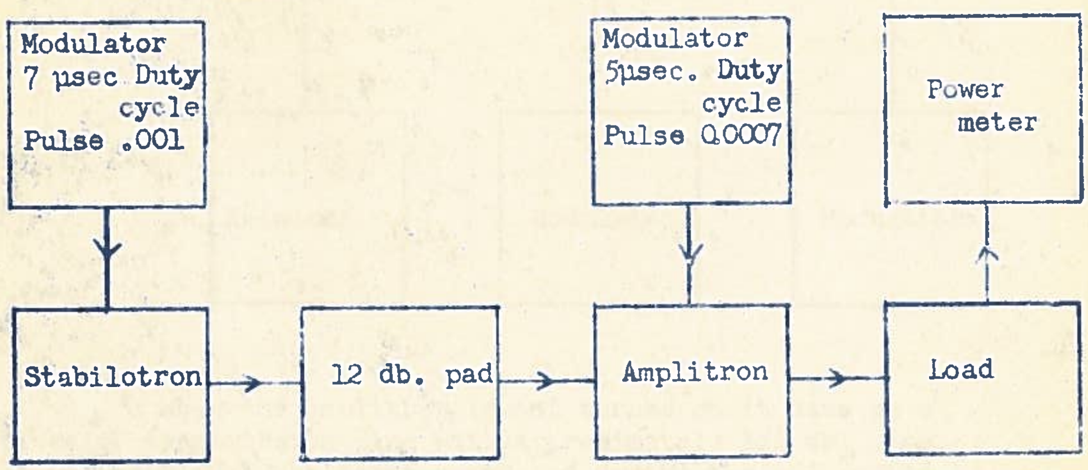
For purposes of further discussion, the platinotron can be considered as a 4 terminal active network with the following properties.



THE "AMPLITRON"

A demonstration of a type QK520 used as an amplitron was given. It was driven by the attenuated output of a QK434 used as a "Stabilotron" operating in the "L" band.

Block Diagram



The spectrum was shown to be of uniformly high quality throughout the band. The power gain appeared to be fairly constant, though it falls off somewhat at lower frequency end of the band.

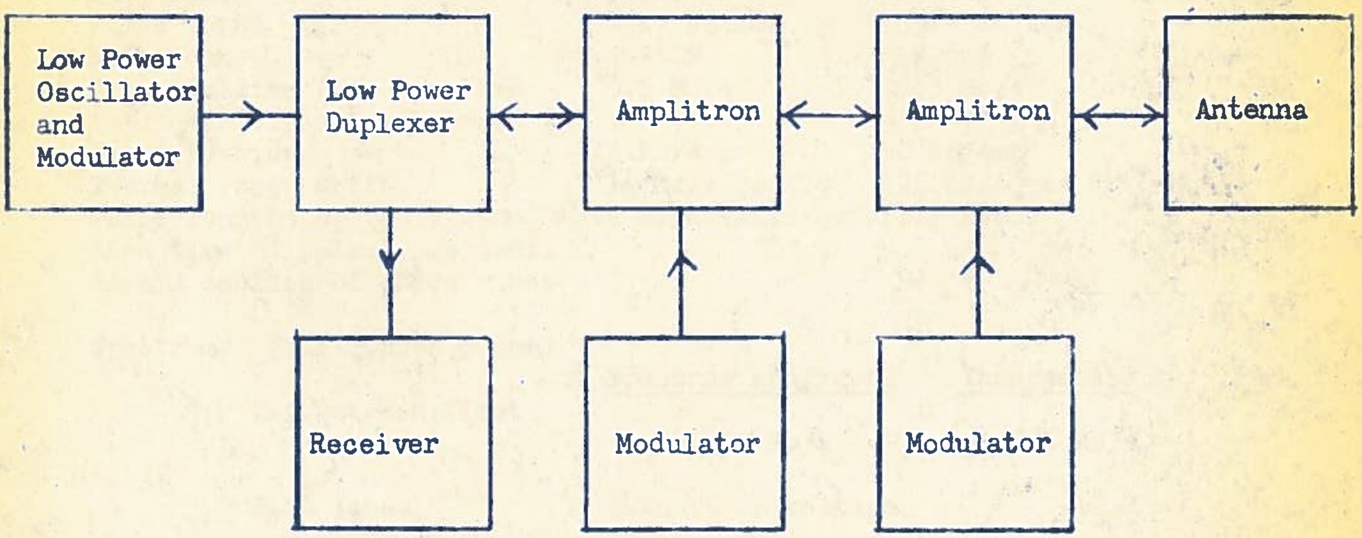
It was stated that the power gain as a function of output power varied as follows:

Power Out	Power Gain	
500 KW	10-14 db	falls off at low end of frequency band.
1 Megawatt	9-10 db	
2 Megawatt	7-8 db	

efficiency 40-60%.

AN APPLICATION OF AMPLITRON

To eliminate problems in high power duplexers, the duplexer could be placed before the amplitron (or Amplitrons in cascade).



When the amplitron is not turned on it acts as a piece of transmission line with approximately 1/4 db. loss. It was said that the noise generated during the off period is negligible.

THE "STABILOTRON"

The "Stabilotron" is the name coined for the ensemble of "Platinotron" and auxiliary equipment necessary to convert it to a stable pulsed oscillator.

"Platinotron" Stabilizing Cavity Terminating Resistor Reflection Transmission lines	=	"Stabilotron"

Report: The Stabilotron: Performance Characteristics and Circuit Analysis -- W.C. Brown
Raytheon Manufacturing Company CONFIDENTIAL.

Characteristics

	QK434	QK507
Frequency	1260-1350 Mc/s	1260-1350 Mc/s
Peak Power (KW)	600	600
Duty Cycle	0.001	0.0024
Pulse input	35KV at 40A	35KV at 40A
Efficiency	40-50%	40-50%
Freq. Pulling (for 1.5 VSWR varied 360° in phase)	0.5 Mc/s	0.5 Mc/s
Freq. Pushing	2 Kc/Amp	2 Kc/Amp
Thermal Freq. drift	3½ Kc/s per °C	25 Kc/s per °C

Pulse lengths up to 17 µsec. have been satisfactorily used.
Rise time of pulse 0.4 µsec.
Liquid cooling of anode vanes

Spectrum: (for 7 µsec pulse)

	Spectrum Analyzer	Theoretical
Δf between first zero	0.300 Mc/s	0.286 Mc/s.
Side lobes	down 15 db voltage	

This spectrum appeared almost a perfect text book example of what a pulse spectrum should be. This was maintained even when the current pulse had a dip to half current in the middle.

STABILOTRON OPERATION

The condition for oscillations in an amplifier is that a portion of the output be fed back to the input with a loop phase shift of $2\pi N$ radians, where N is an integer, and a loop gain $\geq$ unity.

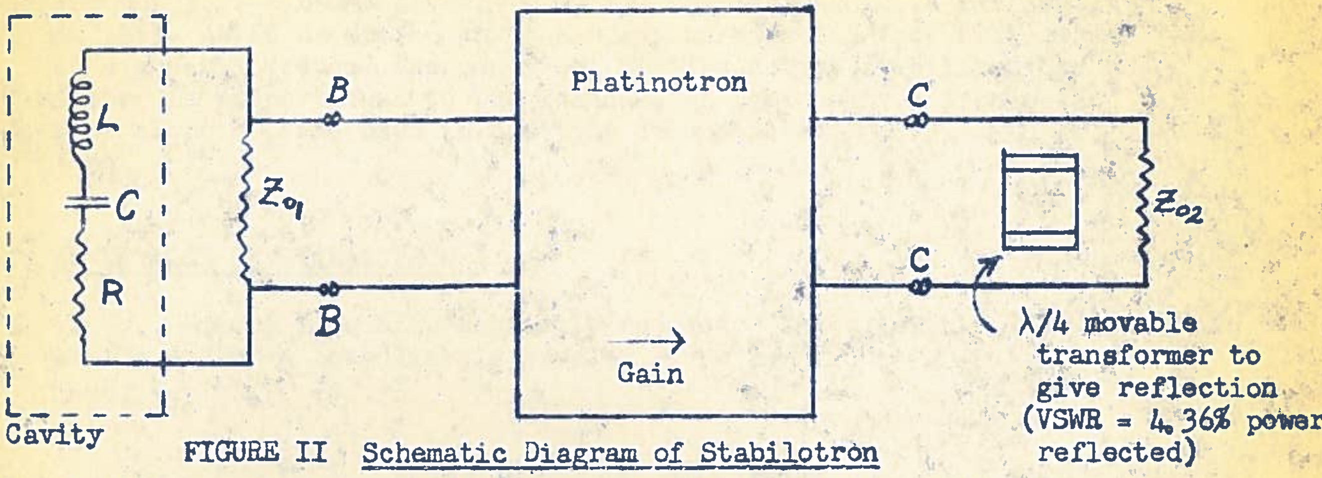


FIGURE II Schematic Diagram of Stabilotron

Consider a disturbance originating at terminals B-B. This will be amplified at terminals C-C, and partially reflected at the reflecting transformer. The portion not reflected is absorbed by Zo_2. The phase of the reflected wave is varied by the position of the reflecting transformer. On arrival back at Zo_1, waves of any frequency except that to which the cavity is tuned will be absorbed in Zo_1. Waves at the frequency of cavity will see a mismatch at the cavity and be reflected back to complete the cycle. The effect is cumulative if loop gain > unity until an amplitude is reached at which the loop gain is unity, provided the requisite phase condition is met. The movable reflection can be replaced by a line stretcher and fixed reflection, and as line stretcher and cavity turns are linear with frequency these can be ganged to give single control tuning.

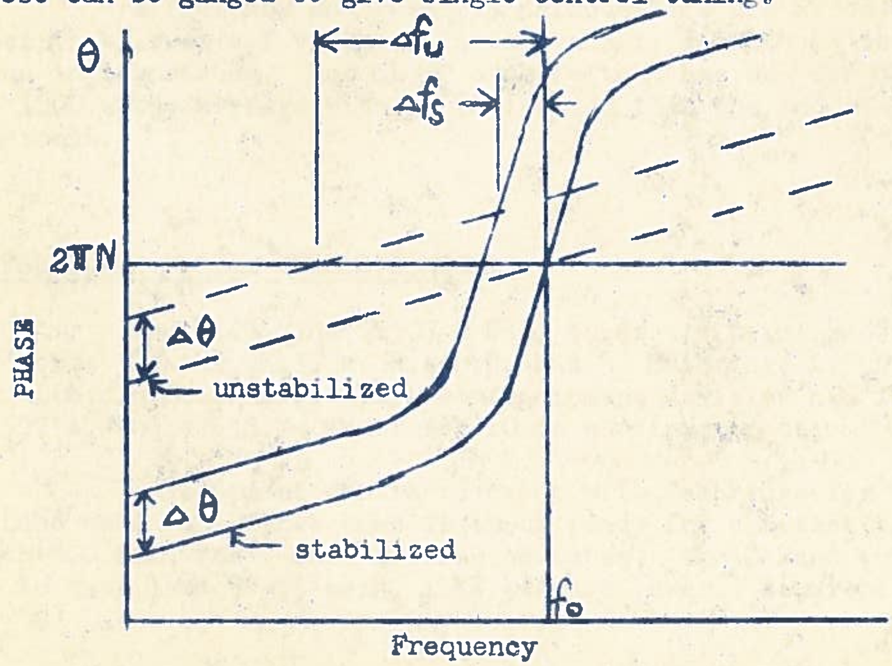


FIGURE III Phase-Frequency Characteristics of Stabilized and Unstabilized Oscillator

Figure III illustrates the frequency stabilizing action of the cavity. Because of the rapid variation of phase with frequency of a L-C-R circuit (cavity) near resonance, a variation in phase shift $\Delta\theta$ due to any cause anywhere in the loop will result in a greatly reduced frequency shift. The actual stabilization factor is proportional to the loaded Q of the cavity. A loaded Q of about 600 was used in the tube demonstrated.

ADVANTAGES OF STABILOTRON

1. Long line effect greatly reduced. The allowable VSWR at the end of a long line is usually given as

$$VSWR_{max.} = \sqrt{1 + \frac{3960}{l_{cm}\ \Delta f}}$$

where l = length of line
Δf = pulling figure of tube for max. VSWR at tube.
With pulling figure reduced by an order of magnitude, long line effect practically ceases to be a problem.

2. Long pulses can be used with good stability. Pulses as long as 17 µsec. have been used with good stability throughout the pulse.

3. It is thought that the use of an invar cavity will reduce drift due to thermal effects.

4. Efficiency and possibly cathode life are aided by the fact that lower r-f voltages to the vane tips exist in the tubes than in magnetrons. One QK507 on life test has run for 1200 hours at 1600 watts average with no indication that the end of life is imminent.

PRESENT AND FUTURE DEVELOPMENTS

The QK434 and QK507 L-Band tubes are being produced at present. Of the QK434's, R.A.D.C. has 3, Cambridge A.F.D.C. 2, and Lincoln Labs. (1). Raytheon equipment division has 10 of the QK507's, and a U.S.N. order for 10 is now in production.

Development contracts exist with Cambridge for an S-Band tube (the first tube is about ready for hot testing.) and with S.C.E.L. for C-Band and X-Band tubes. The C-Band tube (QK505) is to have 1 megawatt peak, 1 KW average power. Apparently tubes have been made, but the frequency range was somewhat off (4200-5500 Mc/s instead of about 5000-6000 Mc/s). The S-Band tube specification calls for peak power greater than 1 Megawatt with about 6 Kc/amp. pushing figure, and a 20-65 peak ampere range. The power output will be limited by arcing in the plumbing. With a better cavity a pushing figure of 3 Kc/amp should be possible.

It is thought that K-Band tubes can also be developed. The following pulling figures are forecast for Stabilotrons:

Band	Pulling Figure	Typical Magnetron Figure
L-Band	0.5 Mc/s	
S-Band	0.92 Mc/s	8 - 12 Mc/s
X-Band	3.0 Mc/s	15 Mc/s
K-Band	7.4 Mc/s	

The buildup time at L-Band is about 0.4 µsec. This should scale for other frequencies (say ≃ 500 ~ of the output frequency).

There is a possibility that C-W tubes of this type can be built to operate at frequencies less than 2000 Mc/s.

Work was done on a 400 Mc/s. tube for Lincoln Labs., but has been discontinued. A 2 Megawatt tube was required, and while powers somewhat in excess of 1 Megawatt were obtained, a magnetron was finally utilized instead. Tubes at this frequency with perhaps 50 KW average power should be possible.

APPLICATION OF QK507 TO EXPERIMENTAL M.T.I. RADAR

A TPS-1D radar was modified by incorporating a new transmitter using the QK507 Stabilotron, and a new pre-amp. and receiver.

	TPS-1D	Modified TPS-1D
Peak Power	500 KW	600 KW
Pulse Length	2 µsec.	3 µsec.
Prf	400 pps	800 pps
Duty Factor	0.0008	0.0024
Transmitter Tube	5J26	QK507
Pulse volts from Modulator	28 KV	35 KV

The new receiver had a bandwidth of 0.5 Mc/S. and an overall noise figure of 9 db.

PERFORMANCE COMPARISON

Ring time using echo box was 16 miles for modified set against 13 miles for TPS-1D. Jet aircraft were seen at 80 miles on modified set, which were not seen on TPS-1D. The experimental model (which is in lab. type racks) is undergoing evaluation and work is to commence soon on a production prototype suitable for field use. (Incidentally, there was no evidence of long line effect in the modified radar.)