Split-Anode Unknown German Magnetron

This magnetron is definitely intriguing. Split-anode magnetrons of the type first described by Habann were quite common in the mid-1930s. A comprehensive description of them is given in many papers and books, as in the Telefunken Technical Bulletin (*1) which also shows photos of some types in production in 1934. Anyway our sample shows solutions devised after the mid 1930s and construction techniques matured over years and available from 1940 onwards.

The magnetron measures about 130 mm, including connecting pins. The bulb is about 30 mm diameter by 60 mm length at the bottom, then the diameter shrinks to about 20 mm in a short transition segment and terminates in a dome, 15 mm diameter by 20 mm length, which contains the magnetron proper. The glass dome is sealed to the lower part of the bulb more or less halfway the transition segment. Getter darkens about 45 mm of the bulb bottom, up to an internal metal baffle. Three 1,5 mm rods entering from below extend through the largest segment of the bulb and support the entire electrode system: the two ends of the filament and the center of the back loop, likely a molybdenum strip which continues to form the anode cylinder first and terminates welded to the two top pins.

-Fig. 2 - Detailed view of the glass bulb at the transition between the large bottom chamber and the top dome containing the magnetron electrodes. The glass seal is clearly visible. Also visible the figure ‘44’ punched on the metal baffle at left and a glass spacer across the output line at right.

The internal electrode structure recalls the one intended for higher frequency applications illustrated in fig. 23.4 of 'Very High Frequency Techniques **(*2)**, with self-contained back loop, the anode supply rod being welded to its central node, as in the draft below.

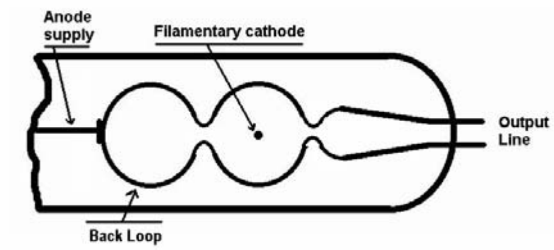

Fig. 3 - Approximate drawing of the internal assembly of the anode-line.

The drawing above is greatly enlarged: Actually the anodes and the back-loop appear as two similar cylinders, each measuring about 5 mm diameter by 6 mm width. The cathode is a filament, likely thoriated tungsten, of about 0.20 or 0.25 mm diameter.

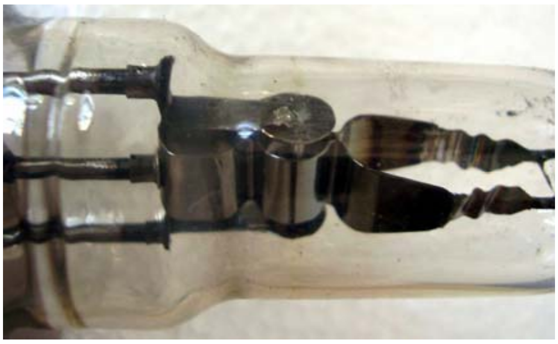

Fig. 4 - Detailed view of the anode-line assembly. Noteworthy is the termination of the three rods to which the blades that hold the filament and the center of the back-loop of the inner line are fixed. Rods are welded inside rivets fixed to the supported elements. We can observe similar solutions into another Siemens magnetron built to -P.T.R. design, the RM4025,

The visual inspection reveals some noteworthy details:

1. **The considerable extension of the getter which covers about three quarters of the internal wall in the lower and widest segment of the bulb. Such a large surface is comparable with the one in audio power tubes, such as the 6L6G. The getter chamber is separated from the electrodes by a baffle, tied to the central rod and therefore raised to the anode supply voltage.**
2. **The neat welding line that connects glass of the lower chamber to the top dome of smaller diameter reveals the use of different glasses. Likely the thinned top end is made of heat-resistant glass. This detail suggests that the magnetron was designed to deliver considerable power at very high frequency, hence the need to decrease the glass diameter, its wall close to the hot anode segments immersed into magnets with considerably small air gap.**
3. **Connections of the internal line towards the output connections are wavy, as if to lengthen their thermal path and allow them to cool before reaching the glass wall. A glass spacer, well visible in fig. 5, is added near the end of the strips, likely to strengthen the structure and dampen possible vibrations.**

Fig. 5 - Close-up view of the internal resonating line strip, connected to the outside by means of wavy sections rigidly interlocked by a glass spacer on the right

It is a split-anode magnetron, therefore of a quite old-fashioned type, designed and optimized to operate at rather high temperatures and therefore capable of dissipating estimated mean power somewhere around ten watts. The execution is very accurate, with construction details typical of the forties, yet it departs from the bandwagon of usual multi-segment Telefunken magnetrons. From the size of the internal system, assuming the length of the internal loop around 1/16 λ, the minimum wavelength can be estimated around 8 cm, therefore compatible with a possible use around 3 GHz.

Almost certainly the filament is thoriated-tungsten measuring about 10 mm length by 0.20 or 0.25 mm diameter. We can roughly estimate its emission considering that such a filament was usually operated around 1.800º K, but could be overheated around 2.000º K for increased emission, of course at somewhat shorter life **(*3)**. Assuming a surface of approximately 6 square mm, our filament could grant an emission of 50 mA at 1.800º K. Depending upon the attainable efficiency, in CW operation we could then expect output power not exceeding 10 watts. In pulsed operation the estimate is more difficult as it depends not only on the emission and efficiency but also on the duty cycle, anyway peak output power well in excess of 10 W could easily be expected. Of course the mean input power should never exceed a few watts, since the heat dissipation only takes place by radiation.

Now let us try to guess when and why this odd magnetron was designed and built. We told before of details which clearly show that our sample was built well after 1940 by a skilled industry, likely Siemens. As we will see, this assumption comes from little details already observed in another Siemens magnetron. Other details lead us to believe that it was intended for operation at high anode temperature, therefore as transmitting tube. Excluding that it was designed for a microwave communication link, we should then investigate on its probable use in a navigation system or in a short-range radar, such as a fire control one, or even in radar jammers by analogy with similar American sets, as the AN/APT-4. Looking at the lists of the WWII German radar jammers **(*4)**, we see a couple of radar jammers designed by Siemens in 1943, one of them using in its first version a 4 W magnetron. Very few data can be found on the Siemens FuMS11 Roderich jammer. Our source gives few details on this set, making confusion between variants. It gives a figure of only 4 watts as 'pulsed power' but this value does not agree with Telefunken data for the RD 2Me, 10 W CW and about 50 W pulsed. Maybe the book refers to minimum power at maximum expected pulse repetition rate. We have to assume that some units were certainly built, since it had gained the code FuMS 11.

***'It was developed in a Schnellaktion** (* this means that it had to be ready within a few weeks from the start in February 1943)* ***after the capture of the Rotterdam device, with a German magnetron (RD 2Me) placed directly in the focus of a 3 m parabolic mirror and tuned in the 2.86-3.16 GHz range. However, with a pulse power of 4 W, the transmitter was far ineffective and was therefore probably never used.'**,* **adding then:**
'The Roland jammer, also by Siemens, first used a magnetron LMS10, later a disc triode LD72 (or LD75?)

Today the reports of the AGR (*Arbeitsgemeinschaft Rotterdam*) committee are the main source of reliable information we can found on the microwave radar and associated sets developed in Germany during the second war. The committee was born early in 1943, after the capture of a British H2S 10 cm radar set near Rotterdam, to coordinate future developments of German microwave components and radar sets. Although with few details, they give information on the sets and on the parallel release of the related electron tubes. **(*5, *6, *7, *8, *9, *10, *11)**

We learn of the P.T.R., Physikalisch Technische Reichsanstalt (today PTB), which was a prestigious institution leading in many fields of physics and metrology, founded in nineteenth century by Werner Siemens **(*12)**. Among its countless activities, in the 1930s PTR had developed and characterized several magnetrons down to 3.7 mm (about 82 GHz) **(*13)**. We also learn that Telefunken had proposed a new six-segment 10 W magnetron, the RD2Me, for the Roderich jammer under development at Siemens. Unfortunately only two samples of the RD2Me were ready in May 1943. Telefunken was unable to supply further units for several months, hence P.T.R. proposed one of its magnetrons to replace the Telefunken one. Siemens undertook to carry out tests with this magnetron and to evaluate which type to use in subsequent productions. The Tube Development Group decided to activate this second source anyway. Almost certainly then our sample is the only evidence still surviving today of a CW split-anode magnetron hastily built in 1943 by Siemens for the Roderich J jammer, according to a 1930s P.T.R. design. This would explain the very accurate manufacture combined with a rather old-fashioned geometry. The table below summarizes the German development of the 10 cm jammers and AGR reports describing the development of the Roderich and of the related tubes.

March 17, 1943 AGR 2	**A survey of CW tubes then suitable for the 10 cm jammer lists a 10 W P.T.R. magnetron, a Telefunken RD2Md (*we know that actually its power does not exceed 1 W)* and an improved variant RD2Me still under development.**
May 19, 1943 AGR 4	**RD2Me, 10 W CW power, is sampled for the first time. Dr. Schultes from Siemens states that both RD2Me and the P.T.R. 10 W magnetrons could be used.**
June 01, 1943 AGR 5	**First CW Roderich ready for tests, 20 more under construction**
July 23, 1943 AGR 7	**Only the first two samples of RD2Me have been supplied at the date for the CW Roderich D. Delivery of 15 more units is expected within the end of July, against a need for at least 300 units. P.T.R. renews its proposal for the production of equivalent tubes made to its own design. Siemens undertakes to run tests with this tube and then decide which type to use in production. Dr. Steimel for the Tube Development Group approves the decision to perfect the P.T.R. equivalent, also for the need to have a second source on such a critical component.**

Sept., Oct. 1943 AGRs 8 - 10 - 11	**The production of RD2Me tubes has yet to take place. Four Roderich D jammers have been completed by Siemens, against only two RD2Me samples. We learn that the production of RD2Me is about to begin in October with the recommendation to reduce the operating heater voltage after a short warm-up time. As of December 12, RD2Me production did not reach the planned 400 units per month**

The book on German jammers and the AGR reports lead us to some considerations about the Roderich jammer and the tubes used through its evolution:

A. The first approach, using a magnetron source delivering a few watts, appears to be effective against one single British H2S set. It could not have effects against attacks in force, the 'carpet bombing' carried out in 1943 by the Allies, with hundreds of bombers guided by many radar sets all active at the same time. On May 19 Dr. Schultes reports of a recent attack by 635 bombers directed by 48 radar-equipped pathfinders. To counteract similar strategies Siemens proposed variants, as a high power transmitter mounted on a high mast, to generate multiple reflections coming from all around (Roderich D). Unfortunately the proposed high power LMS10 magnetron (the German copy of the British CV64) was not tunable, the 1 kW PTR tunable magnetron could not generate useful reflections and suitable planar triodes were still under development.

B. The release of the base pulsed jammer, the Roderich J, suffered severe delays. We can imagine a rather simple project: the magnetron itself with a Lecher line, a keyer and a power supply. Its specs were already outlined in the meeting on March 2 but only four evaluation samples were ready six months later, on September 2, against orders that had reached one thousand units: anything but Schnellaktion! Within the same date Telefunken had just delivered two samples of its 10 W magnetron RD2Me, its volume production being yet to come. Still in September Dr. Steimel blamed the lack of skilled mechanics as the reason of the Telefunken delay.

C. Only on 22 October the AGR 10 report states that the series production of the RD2Me is about to begin, but... There is a short note from Dr. Steimel, the responsible of microwave tube developments, which states that its filament voltage must be reduced in normal operation after a temporary pre-heating at full ratings. This almost insignificant note is the key to understand the true reason for the delay in the delivery of the tubes and at the same time the reason why it was decided to activate an alternate source for the magnetron.

Almost certainly Telefunken, which at the time had no previous experience with power magnetrons for such high frequencies, faced a back-bombardment problem. In a magnetron electrons move along curved trajectories. Depending upon the phase relation between their instantaneous velocity and the alternate electric field superimposed to the DC on the anode segments, some of them are repelled back, hitting the cathode surface. To better characterize his eight-cavity E1189 magnetron, Eric Megaw at GEC built two laboratory prototypes with side glass window in order to perform pyrometric measurements of the cathode temperature. By the way one of the Megaw's prototypes is today in our collection, **E1189 Prototype**. In his 1946 paper on high-power magnetrons **(*14)** he pointed out 'the output at 6 μs was independent of heater voltage down to zero...', having observed in his previous six-cavity prototypes that back-bombardment alone was enough to keep magnetron operating even removing the heater voltage. In our case the back-bombardment could have caused uncontrolled overheating and unexpected early failures of the filamen. Failures were erroneously attributed to the inexperience of the personnel processing the thoriated tungsten spiral filament. Only after in-depth investigations which led to understanding the true cause of the failures, the solution of reducing the filament voltage after the warm-up was proposed. Everything leads to the conclusion that such a problem arose with the RD2Me magnetron and that Telefunken, certainly pressed by many other commitments, had been slow to react and suggest the right solution.

In these circumstances, we understand the PTR proposal for its own alternative solution, maybe dated but already fully tested and readily reproducible in volume. We could also understand why, after a delay of some five months, Dr. Steimel and Siemens decided to start its production. We do not know how many magnetrons were built overall to the PTR design. Certainly two or more of the four Roderich jammers in evaluation in September were equipped with this one, since Telefunken had not yet started its production. Almost certainly some hundreds Roderich jammers were eventually made, as in December in the AGR report 11 **(*11)** we read that Siemens could not reach the planned quantity, due to difficulties from Telefunken to deliver 400 RD2Me magnetrons per month. Then we can assume that other tubes were built to balance the missing deliveries from Telefunken.

It remains to be determined whether our sample could correspond to one of the pre-war PTR designs. Based on other publications regarding split-anode magnetrons, particularly by Philips **(*15)**, Kilgore from RCA **(*16)** and other subsequent articles, our magnetron design could be dated between 1935 and 1938. In those years several countries were investigating for tubes that could operate at frequencies higher than those obtainable with gridded ones. Our sample differs from the basic split-anode types with external resonant circuit and also differs from those with internal resonator described by Kilgore. Its typology, with internal shorting back-loop and external part of the resonant line, is described in detail in Very High Frequency Techniques, 1943 **(*2)** talking of CW magnetrons specially designed for radar jammers. At very-high frequencies this structure allows to vary the frequency with a shorting jumper across the external extension of the resonant Lecher line (trombone), at the same time preventing mode jumping across the full tuning range.

Our research was particularly difficult as it concerned a very niche topic among the many activities in which the prestigious institute PTR, Physikalisch-Technische Reichsanstalt - today PTB - excelled and also because of our ignorance of the German language. Decisive help came from Karl Heinz Gollmann, the previous owner of the magnetron. He provided links to several dozen documents, English translations of many paragraphs, titles of books of the time and addresses of booksellers. A first search in the page dedicated by H.T. Schmidt to German magnetrons **(*17)** returns a few types made by Siemens to PTR designs but none of them fitting the wavelength range of the Roderich one. Digging for papers from the second half of 1930s we found the description and the photos of a type very similar to our sample in the book Einfürung in Theorie und Technik der Dazimeterwellen, written by Otto Groos in 1937 **(*18)**. The magnetron had been designed for operation at 8 cm wavelength at the Research Institute of the Deutsche Reichspost, DRP. Almost certainly its innovative design should be dated the same year, since in 1936, just one year before, H.E. Hollmann in his "Physik und Tecnnik der Ultrakurzen Wellen" in Germany **(*19)** and Kilgore at RCA **(*16)** just gave types with the full resonator inside the glass bulb as advanced investigation for very high frequencies,.

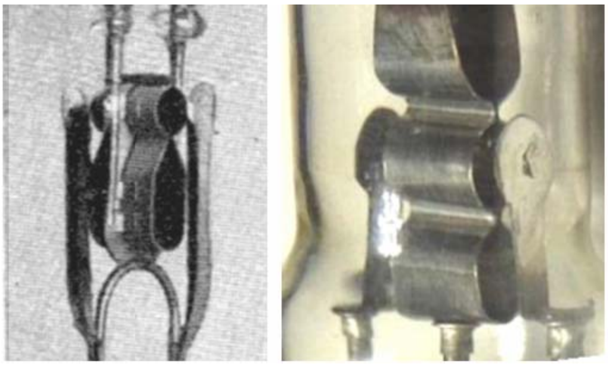

Fig. 6 - Close-up view of anode shapes for both the DRP split-anode prototype, 1937, and our sample.

The connection between the 2 W magnetron built at DRP and the one proposed by PTR to Siemens is not known. PTR was certainly involved in every advanced researches, in this case also for its leadership in the metrological aspects faced when working at frequencies never before explored. In the case of the Rotterdam-Gerät, it was just PTR at Zeulenroda in Thuringen, that conducted all the comparative tests between the captured British H2S and the copies built by Telefunken **(*20)**. Just a guess but the link between DRP and PTR could be found in the figure of Dr. Karl Kohl, one of the leading high-frequency experts in Germany. We found that as guest researcher he carried out experiments on magnetrons at PTR Berlin until 1939 **(*21)**. But he was also active as an independent consultant: in addition to having registered around fifty patents **(*22)**, he had collaborated with GEMA when they built the early DeTe prototypes based on Philips magnetrons **(*23)**. Maybe that the development of the DRP 2 W magnetron was actually run at PTR. In this case, considering the different application, maybe that the PTR 10 W prototype we are looking for is the same design, its power specs recalculated for intermittent use instead of the original continuous duty. In any case we have clear evidence that the solution of a split-anode geometry with back loop was among the most advanced investigation frontiers in Germany between the second half of 1936 and the early 1937 and therefore certainly in the sphere of interest of PTR researchers.

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In summary AGR reports evidence of the need for a magnetron of about 10 W, the one we believe derived from the P.T.R. design, in order to produce the FuMS 11 Roderich jammers. Though never reading there details to identify our prototype, indirect confirmation comes from the following remarks, all confirming our identification:

- **Siemens had been committed to build 400 Roderich jammers per month.**
- **Telefunken was unable to deliver its magnetron for a long while and when production began around the end of 1943 it was unable to deliver the required quantities. A second source had been explicitly solicited for the Telefunken tube**
- **Siemens undertook to test the P.T.R. equivalent magnetron. P.T.R. owned the proper experience and some of its designs, likely developed in the second half of the '930s, were suitable for the specific use. The split-anode magnetron with internal back-loop was undoubtedly known at P.T.R. for its superior efficiency and stability at very-high frequencies.**
- **A magnetron very similar to our sample had been made back in 1937 by the DRP, Deutsche Reichspost, for use in microwave links. PTR could well have participated in its development and/or in its subsequent tests.**
- **The figure '44' punched on the internal baffle could indicate the year of construction of our sample, 1944.**

I kindly ask all the people who have further information, maybe books, papers, or technical bulletins from the mid thirties onwards, to contact me at the addresses below.

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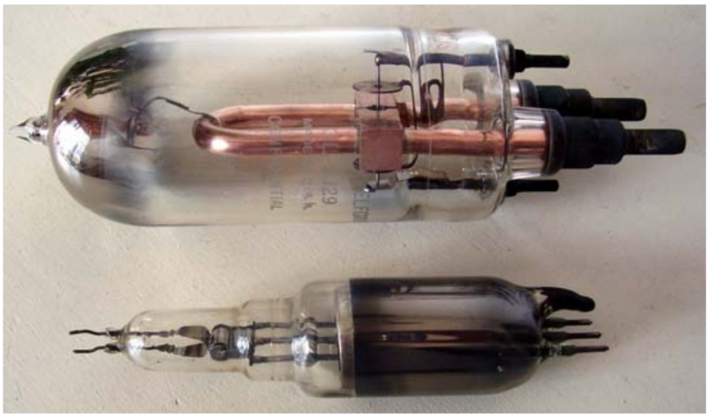
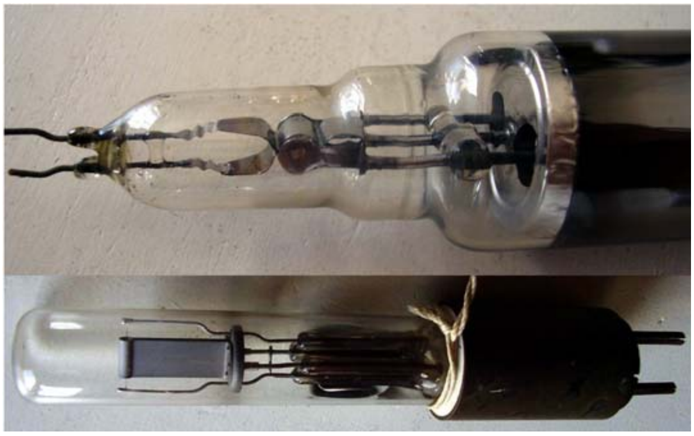


Parallel tracks in the development of magnetrons for radar jammers. Our sample is photographed below a 5J29, the internal loop split-anode magnetron developed at the Harvard University (*2) and used for example in the radar jammer AN/APT-4. 5J29 was useful from about 350 to 770 MHz. One major difference is in the length of internal loop, about 1/4 wavelength for the GE types and ranging from 1/8 to 1/16 wavelength for the German types.



Our unknown sample compared with a quite late P.T.R.-Siemens RM4025 10 GHz split-anode magnetron. We can appreciate similarities even in construction solutions, such as the eyelets that firmly connect supporting and supply rods to the middle of anode structure.

Acknowledgments:

Valuable help was provided by Karl-Heinz Gollmann, who first provided us with this very rare sample and then suggested the publications on German radar jammers, also translating relevant parts from the German reports of the AGR committee, the one that was created in 1943 to coordinate developments of microwave devices.

References

1. Telefunken Zeitung, december 1934: https://www.cdvandt.org/Runge-magnetron.pdf
2. Very High Frequency Techniques, Vol II - Chap. 23, Harvard University, 1947
3. Stiles W. S. - Thermoionic emission, H.M. Stationery Service, London 1932
4. Die deutschen Funkstörverfahren bis 1945, Fritz Trenkle, AEG-Telefunken
5. AGR (Arbeitsgemeinschaft Rotterdam) report 2, March 17, 1943:
6. AGR (Arbeitsgemeinschaft Rotterdam) report 4, May 19, 1943:
7. AGR (Arbeitsgemeinschaft Rotterdam) report 5, June 1, 1943:
8. AGR (Arbeitsgemeinschaft Rotterdam) report 7, July 23, 1943:
9. AGR (Arbeitsgemeinschaft Rotterdam) report 8, September 2, 1943
10. AGR (Arbeitsgemeinschaft Rotterdam) report 10, 22 October, 1943:
11. AGR (Arbeitsgemeinschaft Rotterdam) report 11, 12 December 1943:
12. Die Physikalisch-Technische Reichsanstalt, Rudolf Huebener - Heinz Lübbig
13. CIOS file XXXI-36, Physikalisch-Technische Reichsanstalt 1/441:
14. Eric Megaw, The High-Power Pulsed Magnetron: a Review of early developments, 1946
15. Philips Technical Review, Modern transmitting Valves, April 1937
16. Magnetron oscillators, G.R. Kilgore, Aug. 1936
17. http://www.hts-homepage.de/Wehrmacht/Magnetronliste.html
18. Einfürung in Theorie und Technik der Dezimeterwellen, Otto Groos, Leipzig 1937, selected pages
19. Physik und Tecnnik der Ultrakurzen Wellen, H.E. Hollmann, 1936
20. PTB Mitteilungen 1, 2013 - Die Physicalisch-Technische Reichsanstalt in Thüringen
21. “PTB Mitteilungen Fachjournal, Heft 1, März 2013”
22. https://www.fuerthwiki.de/wiki/index.php/Karl_Kohl
23. GEMA: Birthplace of German Radar and Sonar, harry von Kroge

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