

W. W. Hansen, Microwave Physics and Silicon Valley



William Webster Hansen (1909-1949)

Founder of Microwave Electronics

Hansen Chronology

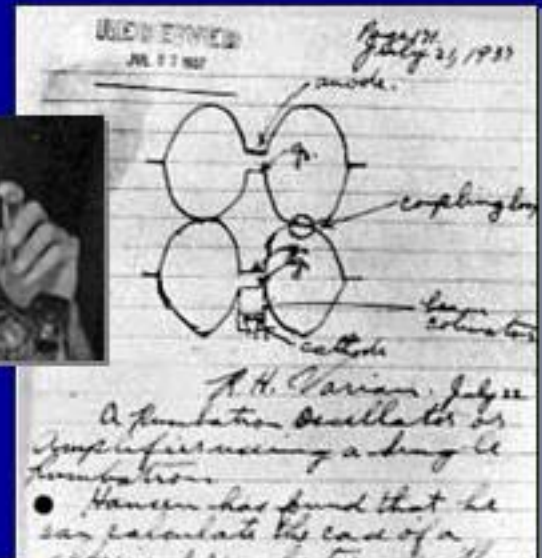
- Born Fresno, CA 1909
- Stanford AB 1929, PhD 1933
- MIT: Physics Post-doc 1933-34
- Stanford: Professor 1935-40
- Sperry + MIT Rad Lab 1940-45
- Stanford : Professor 1945-49
 - NMR with Bloch
 - Microwave Lab, Founder, Director
 - High power klystrons
 - Linear accelerator “Mark” family
- Untimely death 1949



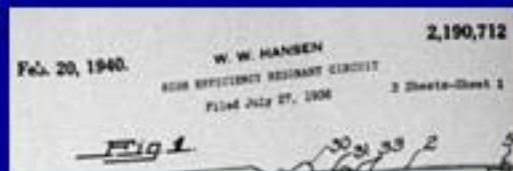
Hansen's Inventions 1935-37

At this point I had completed the essential idea of a hollow conductor used as a resonator to develop fields to accelerate electrons.

All this occurred before January 10, 1935 for on this date I gave a connected account of the idea before the Physics Journal Club in a talk entitled "How to Get 10^8 volts Cheap"(27).



Linear Accelerator 1935
(this is a post-war photo)



"Rhumbatron" Cavity Resonator 1936



Klystron 1937

Hansen's Cast of Characters

- Professors
 - David L. Webster
 - George R. Harrison
 - John C. Slater
 - P. M. Morse
- Collaborators
 - Russell & Sigurd Varian
 - F. E. Terman
 - Felix Bloch

Protégés

- John Woodyard
- Edward L. Ginzton

Inventors of the Klystron



R. & S. Varian, Webster, Hansen, Woodyard

Key Relationships

Varians & Harrison



R. Varian



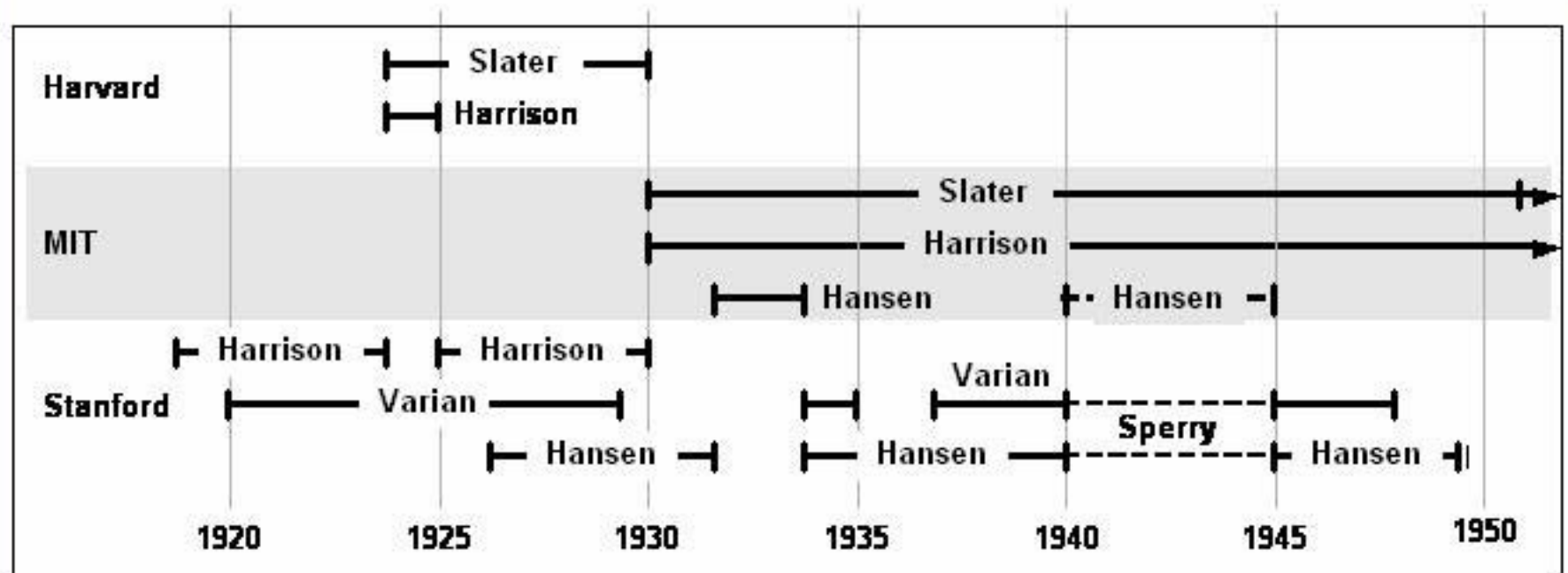
S. Varian & Hansen



Harrison



Slater



Hansen's Cavity Resonators

- Spherical Cavity: the "Rhumbatron"
 - Spherical functions theory: non-radiating resonator
 - Lower loss, higher voltage, Copper insulator
 - Other shapes: cylindrical, re-entrant, rectangular

*is subject to the same troubles as in
but if we take
 $R = \frac{(J_0'(\beta_0 a))^2}{2} \frac{1}{P}$
we will have the shortest
useful for our purposes.
 $R = \frac{1}{2} \frac{n^2 (J_0'(\beta_0 a))^2}{\int_0^a J_0^2(\beta_0 r) r dr}$*



"Washtub" Rhumbatron Acorn-tube rectangular

Invention of Klystron

- Varians seek out Hansen, May 1937
 - Sig Varian: Bomber defense? 1936
 - Stanford: \$100 funding, use of lab, no pay
 - Velocity modulation with cavities solves transit time limit
 - Notebook entry July, working August



Room 404

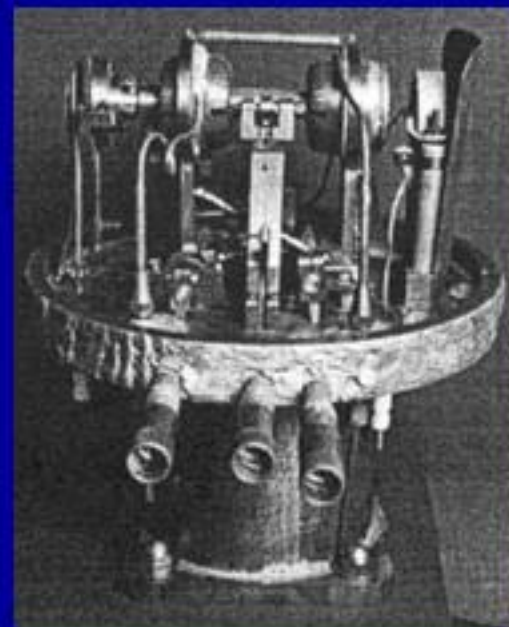


Klystron Model A

Sperry Funding

(c) The Sperry Gyroscope Company, Inc., of New York, has, however, shown increasing interest in the matter and has definitely proposed to appropriate up to \$25,000 to cover the expense to date of the experimental work on these devices, and to provide during 1938 for their fullest and most rapid development, consistent with efficiency, in return for which that Company would receive an option, at a 5% royalty, for the commercial rights on these patents. We also

- Sperry's \$25,000: "Colossal"
 - 1939: Sperry opens in San Carlos, CA
 - Visitors log, all the key people
- Who calls the tune?
 - Staffing, priorities
 - Patents, secrecy
 - 1940: Group moves to NY for WWII



Klystron Model B

First Klystron Microwave Systems

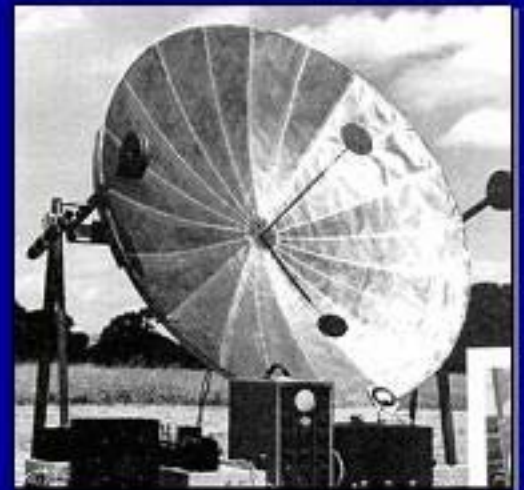
- John Woodyard's projects



MIT-CAA Blind Landing Test
Boston, 1939



Woodyard & Hansen



Radar
Stanford, 1939-40

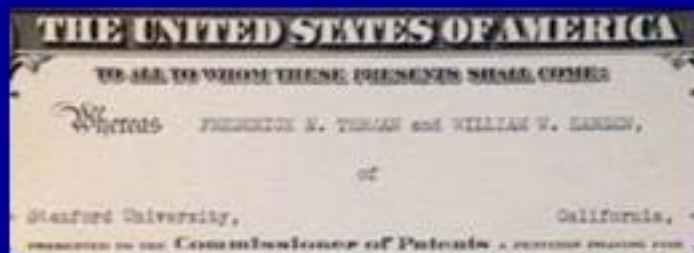
Ed Ginzton, Hansen's Protégé

- BS '36, MS UC, to Stanford 1937
 - Terman sends Ginzton to Hansen 1939
 - EE under Terman, PhD
 - With group to Sperry 1940
- Megawatt klystron with Chodorow 1949
- Succeeds Hansen as MW Lab Director
- "Hansen Labs"
- SLAC Director
- Varian CEO



Terman & Hansen

- Terman admired Hansen
 - Shared interest in antennas
 - Sent Woodyard & Ginzton to him
- Director of Harvard RRL in WWII
 - Learned university finance from Harvard CFO
 - With Bloch, mentored Microwave Lab proposal
- Post-war Dean, Provost
 - “Steeple of Excellence”
 - Government funding
 - Stanford Industrial Park, grew to Silicon Valley



Impact of Klystron Invention

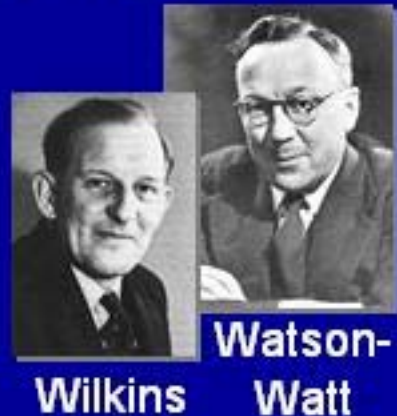
- **Raised Stanford to national level**
 - Corporate & Govt. funding
 - Stanford Industrial Park
 - Nobel-prize faculty
 - Donor endowment
- **Made possible:**
 - Airborne radar (WWII)
 - Linear accelerators (SLAC)
 - Microwave industry (Varian)
 - Silicon Valley



"Three Men and a Tube"

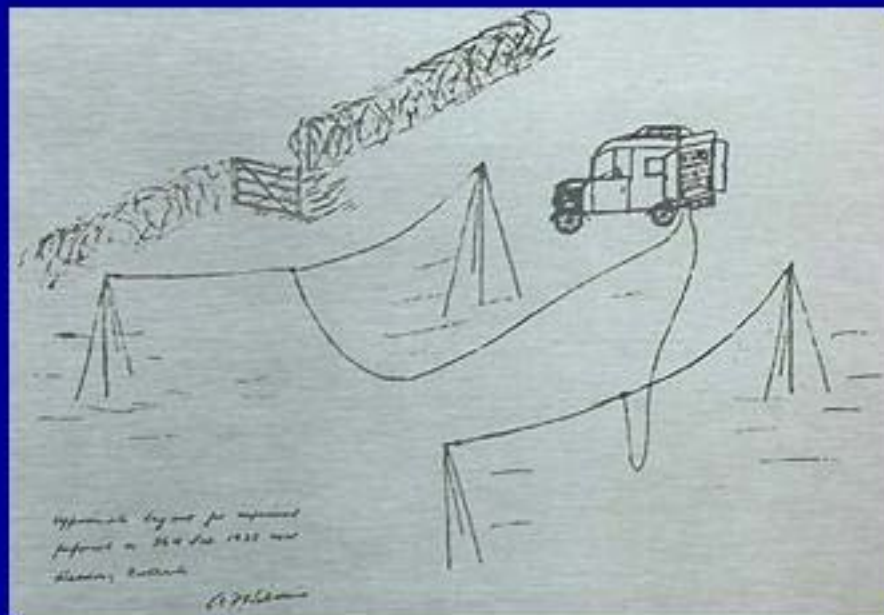
UK Radar: Daventry & TRE 1935

- Passive detection with BBC 6 MHz
 - Watson-Watt WWI lightning network
 - Immediate funding: TRE to develop RDF

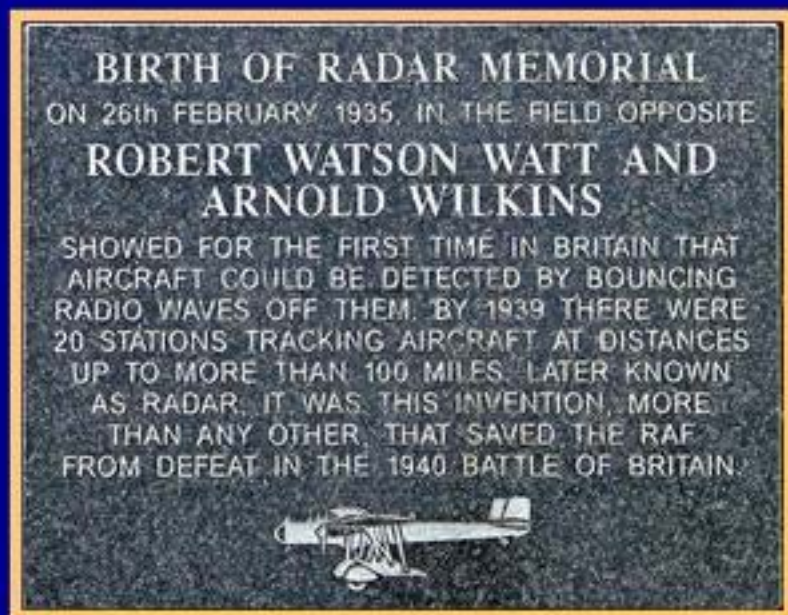


Wilkins

Watt



Wilkins' sketch



Daventry Memorial

Chain Home – Won Battle of Britain

- HF RDF system 1937-40
 - 120m steel TX, 80m wood RX towers
 - 350 KW 20-30 MHz Transmitters
 - Networked to central operations room
 - Conclusion: Need microwave for airborne



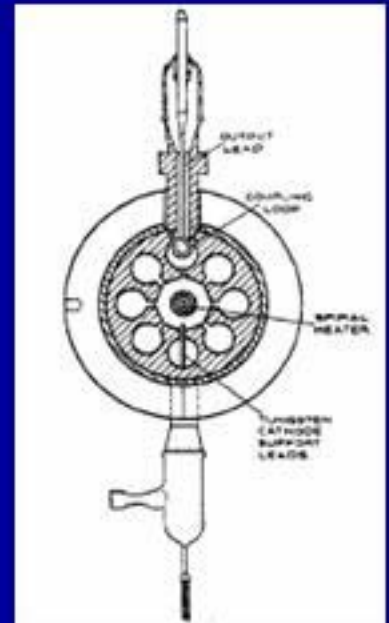
Vacuum Tube History

- Vacuum pump, glassworks
- Crookes' Tubes
- Edison Effect: Fleming Valve
- DeForest Audion
- RCA patents
- Transit-time limit, no microwaves
- Klystron: Problem solved!
- Cavity Magnetron



The Cavity Magnetron

- Randall & Boot, Birmingham 1940
 - Based on klystron & cyclotron
 - Made WWII airborne radar possible



Historical Notes on the Cavity Magnetron

HENRY A. H. BOOT AND JOHN T. RANDALL

mer of 1939. Such new words as klystron, rhumbatron, and velocity modulation arose in papers by Hansen and the Varian Brothers, and these intriguing new concepts discussed at colloquia in the department.



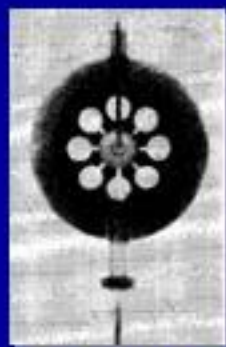
Magnetron
cavities

500 KW
Magnetron
(without magnet)

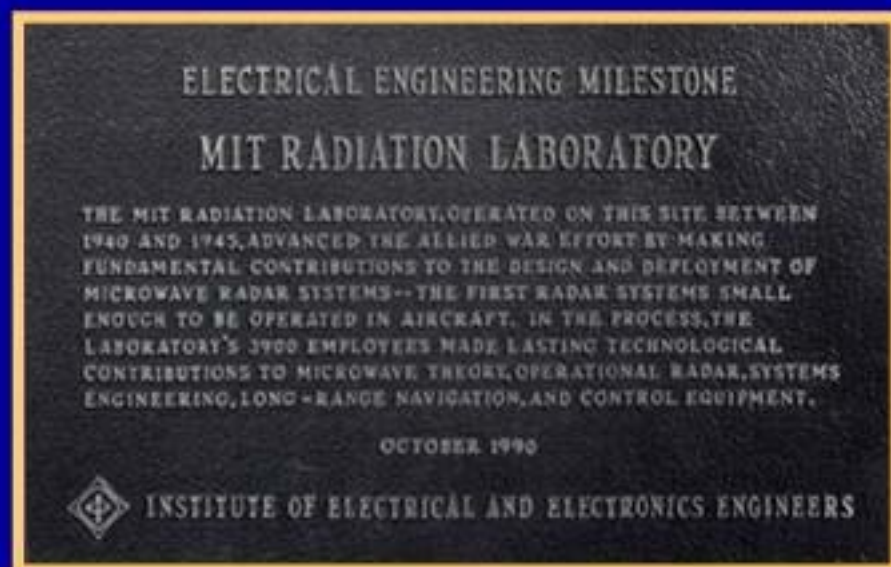


MIT Radiation Laboratory

- NDRC Loomis Microwave Committee
 - Search for radar microwave source
 - Tizard mission reveals magnetron Aug. 1940
- MIT Rad Lab founded Oct. 1940
 - 4000 staff, \$1.5B radars
 - Did radar win the war?



X-ray



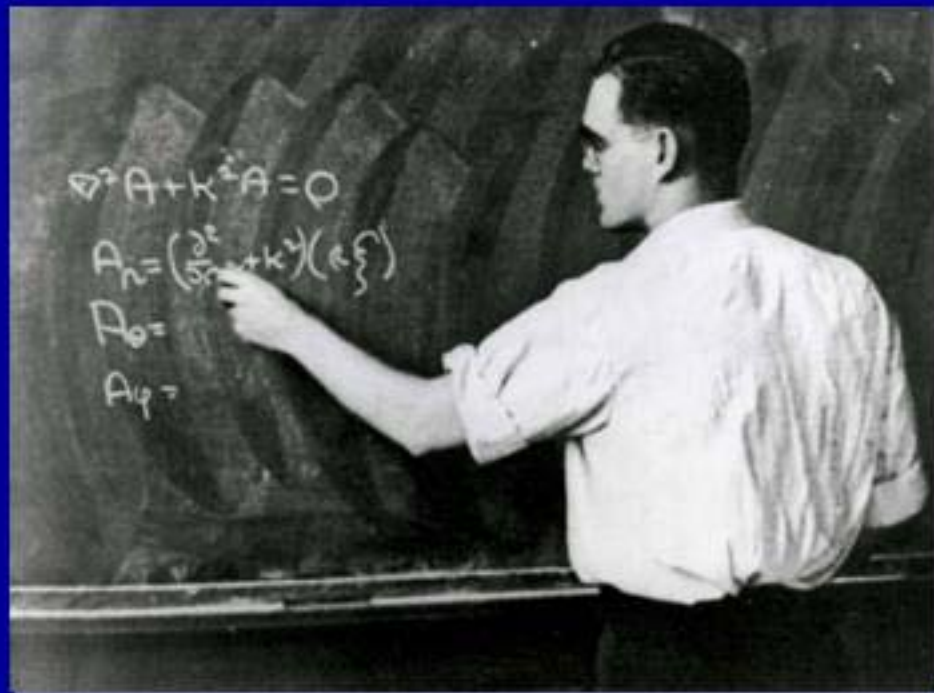
Hansen's MIT Rad Lab Lectures

Dear Professor Hansen:

The National Defense Research Committee established by order of the Council of National Defense to handle research on instruments of war in the present national emergency has appointed you as a consultant in Division D

Oct 1940

- Commuted weekly from Long Island
- "Everyone came"
- Ditto copies
 - 1200 pgs
 - Classified
- Rad Lab "Bible"
- Never published



Bloch, Hansen & NMR

- Bloch, Hansen & Packard 1946
 - Bloch Nobel '52
 - Shared with Purcell (Harvard)
- Applications
 - Chemical analysis
 - Imaging (MRI)



Felix Bloch, Bill Hansen

Linear Accelerators

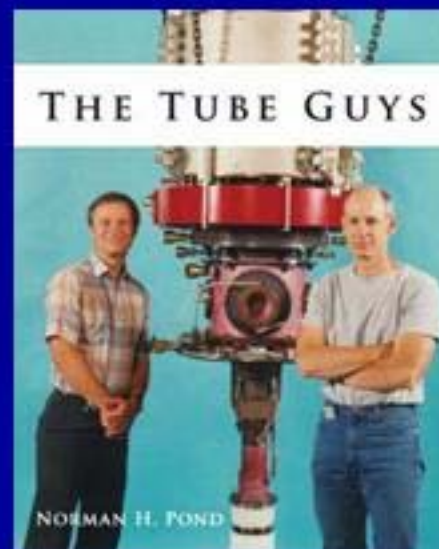
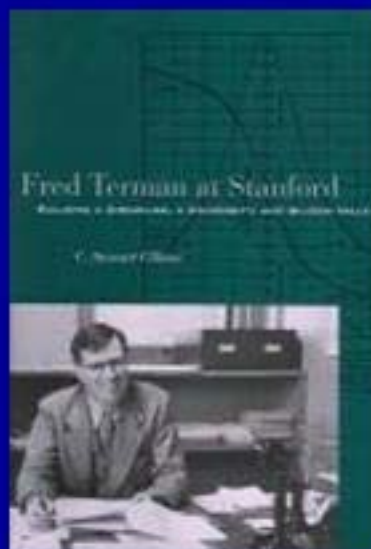
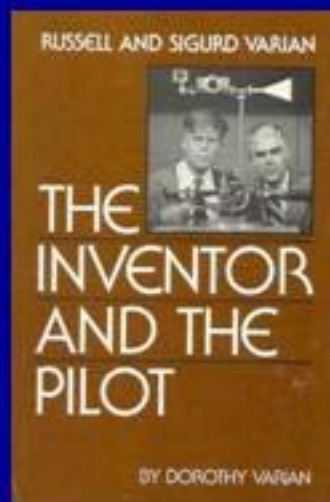
- **Precursors**
 - Rutherford challenge 1928
 - Wideröe, Sloan, Hansen, Alvarez
- **Stanford linear accelerators**
 - Iris cavity loaded waveguide
 - Megawatt klystrons applied
 - Mark series: scalable to SLAC
 - Microwave tube business precedes Silicon Valley



First 1 m. section

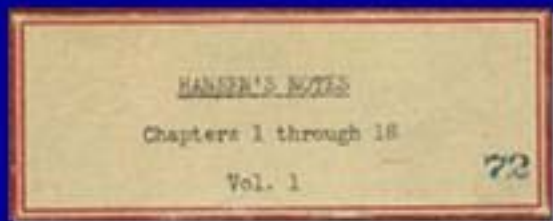
Microwave Tubes and Stanford

- 1960's: Half US microwave tubes 10 miles
- Basis of Silicon Valley
 - Intellectual & financial culture attracts entrepreneurs
- Hansen legacy

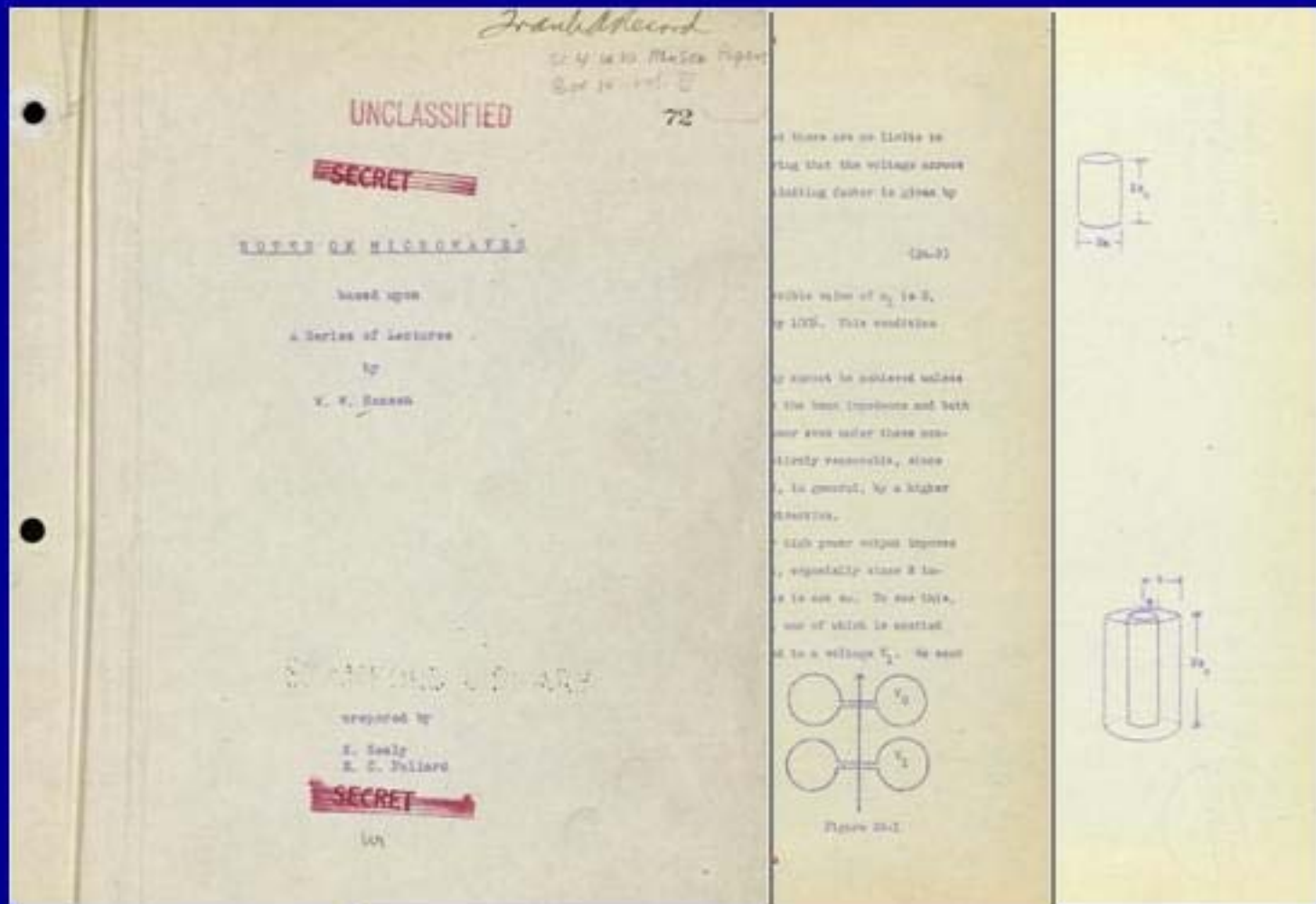


Finding Hansen's Notes

- Stanford Archives
 - Hansen, Varian, Ginzton, Terman, Webster papers



The Notes: Page Views



Publishing Hansen's Notes

- May 27, centenary of Hansen's birth

Works of the Research Institute are widely available in printed format and in books of articles. About others, but missing perhaps in a wide appreciation of the general impact on the development of Swedish and Western Europe, Hansen's research, appearing unconnected from a regional university, was the result of the exceptional genius of Swedish in Uppsala Valley.

About the author

David B. Leeson is a Distinguished Professor of Electrical Engineering at Bradley University, Illinois. He received his Ph.D. from the University of Illinois at Urbana-Champaign in 1974 and worked for the U.S. Army Research Office-Durham, North Carolina, and the U.S. Army Research Office-Wright-Patterson, Ohio. He is the author of the book "The History of Microwave Engineering" published by Artech House in 2005.



John C. Slater "Hansen more than anyone else deserves to be considered the founder of microwave electronics" (Microwave Electronics, 1950)

Edward L. Ginzton "Dr. Hansen can be considered, as the founder of the modern microwave field." (Microwave Measurements, 1957)


W.W. Hansen

Founder of Microwave Electronics

Leeson

W. W. Hansen

Founder of Microwave Electronics



David B. Leeson
1946-2012

Soda Springs Press


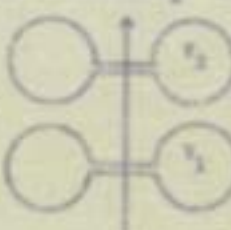



Figure 10-1

...the microwave field... the following is true for the case of dipole... 200 watts, a equal to 10 m, of equal to 10⁴ sq... 100 m, of... long distance... has been reported... range varies directly as the wave length, less R₀... communication with small power is entirely feasible... That is... problem... transmitting and... with area is also directed towards an antenna to lead

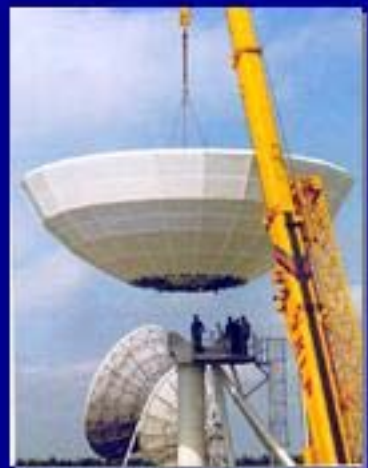
The Swedish physicist, William Wilhelm Hansen, had to... Hansen's research... the history of microwave electronics... the development of the high power klystron and cavity... Hansen's research... the history of microwave electronics... the development of the high power klystron and cavity... Hansen's research... the history of microwave electronics... the development of the high power klystron and cavity...

Recognized later in the text, and Hansen was asked to... Hansen's research... the history of microwave electronics... the development of the high power klystron and cavity... Hansen's research... the history of microwave electronics... the development of the high power klystron and cavity...

After the war, Hansen started in the first administration... Hansen's research... the history of microwave electronics... the development of the high power klystron and cavity... Hansen's research... the history of microwave electronics... the development of the high power klystron and cavity...

Personal Reflections

- CEO, California Microwave 1968-1994
 - Objectives: Independence, control, enjoyment
 - Background: Caltech, MIT, Stanford PhD
 - Experience: Hughes radar & satellite, Applied Tech
 - Products: Radar, terrestrial, satellite, news, data, WiFi
 - Customers: Infrastructure users (AT&T, US Govt)



Pre-Silicon Valley Investors

- **Investor climate before the boom**
 - Individuals, blank check, living rooms, one round
 - Now institutionalized - "Every kitten becomes a cat"
- **Our plan: internal development & ventures**
 - Funded from retained earnings, efficient R&D
 - Founded 1968, public 1972, 100:1 return



Acknowledgments

- C. Stewart Gillmor
- Margaret Kimball, Archivist and Stanford Archives
- Stella Ota, Stanford Physics Librarian
- Jean Deken, SLAC Archivist
- Henry Lowood, Curator, Stanford Hist. Sci. & Tech.
- Alan Harvey, Stanford University Press
- Phil Wessells and Tin Hoang, QOOP, Inc.
- Photos courtesy of Stanford University, SLAC, Varian family, California Microwave