# Wullenweber

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AN/[FLR-9](http://en.wikipedia.org/wiki/FLR-9) Wullenweber antenna array near Augsburg, Germany

The **Wullenweber** (the original name introduced by Dr. Hans Rindfleisch was Wullenwe**v**er) is a type of Circularly Disposed Antenna Array (CDAA) sometimes referred to as a Circularly Disposed Dipole Array (CDDA). It is a large circular antenna array used by the military to [triangulate](http://en.wikipedia.org/wiki/Triangulation) radio signals for radio navigation, intelligence gathering and search and rescue. Because of its immense size and huge circular reflecting screen, the antenna is colloquially known as the *elephant cage.* Wullenwever was the World War II German [cover](http://en.wikipedia.org/wiki/Cover) term used to identify their CDAA research and development program, its name is unrelated to any person involved in the program.

Wullenwever technology was developed by the German navy communication research command, Nachrichtenmittelversuchskommando (NVK) and [Telefunken](http://en.wikipedia.org/wiki/Telefunken) during the early years of [World War II](http://en.wikipedia.org/wiki/World_War_II). The inventor was NVK group leader Dr. Hans Rindfleisch, who worked after the war as a Technical Director for the northern Germany official broadcast ([Norddeutscher Rundfunk - NDR](http://en.wikipedia.org/wiki/Norddeutscher_Rundfunk)). Technical team leaders were Dr. Joachim Pietzner, Dr. Hans Schellhoss, and Dr. Maximilian Wächtler. The latter was a founder of Plath GmbH in 1954 and later a consultant to both Plath and Telefunken.

Dr. Rolf Wundt, a German antenna researcher, was one of hundreds of German scientists taken to the U.S. by the Army after the war under [Operation Paperclip](http://en.wikipedia.org/wiki/Operation_Paperclip). He arrived in New York in March, 1947 on the same ship as [Wernher Von Braun](http://en.wikipedia.org/wiki/Wernher_Von_Braun) and his wife and parents. He was first employed by the U.S. Air Force, then by GT&E Sylvania Electronics Systems on Wullenweber and other antenna projects.

Although the three men retired in West Germany, some of their second-echelon technicians were taken to the [USSR](http://en.wikipedia.org/wiki/USSR) after the war. At least 30 Krug arrays -- the cover term for the Soviet CDAA program -- were installed all over the Soviet Union and allied countries in the 1950s, well before the U.S. military became interested and developed their own CDAAs. Several Krugs were installed in pairs within less than 10 km kilometers of each other, apparently for radio navigation purposes. At least four Krugs were installed near Moscow; just to the north, east and south ([55.46408° N 37.3698° E](http://stable.toolserver.org/geohack/geohack.php?pagename=Wullenweber&params=55.46408_N_37.3698_E_scale:10000)) of the city. The Krugs were used to track the early Sputnik satellites, using their 10 and 20 MHz beacons, and were instrumental in locating re-entry vehicles.

The first Wullenwever was built during the war at Skisby (in German: Hjorring), Denmark ( [57°28′39″N, 10°20′04″E](http://stable.toolserver.org/geohack/geohack.php?pagename=Wullenweber&params=57_28_39_N_10_20_04_E_%7b%7b%7b9%7d%7d%7d)). It used forty vertical radiator elements, placed on the arc of a circle with a diameter of 120 meters. Forty reflecting elements were installed behind the radiator elements, suspended on a circular wooden support structure with a diameter of 112.5 meters. To more easily obtain true geographic bearings, the north and south elements were placed exactly on the North-South meridian. The Soviet Krug arrays also use the 40 radiator Wullenwever configuration.

The array in Skisby was extensively studied by the British, then destroyed following the war in accordance with the Geneva Convention. Dr. Wächtler arranged to have a second array built, at Telefunken expense, at Langenargen/Bodensee, for further experimentation after the war. In the years following the war, the U.S. disassembled the Langenargen/Bodensee array and brought it back to the U.S., where it became known as the "Wullenweber" array.

Professor Edgar Hayden, then a young engineer in the [University of Illinois](http://en.wikipedia.org/wiki/University_of_Illinois_at_Urbana-Champaign) Radio Direction Finding Research Group, led the reassembly of the Wullenweber, studied the design and performance of [HF/DF](http://en.wikipedia.org/wiki/HF/DF) arrays and researched the physics of HF/DF under contract to the U.S. Navy from 1947 through 1960. His research is still used today to guide the design and site selection of [HF/DF](http://en.wikipedia.org/wiki/HF/DF) arrays. Records of his research are available in the university's archives. Hayden was later employed by [Southwest Research Institute](http://en.wikipedia.org/wiki/Southwest_Research_Institute) where he continued to contribute to HF direction finding technology.

Hayden led the design and development of a large Wullenweber array at the university's Bondville Road Field Station, a few miles southwest of Bondville, IL. The array consisted of a ring 120 vertical monopoles covering 2-20 MHz. Tall wood poles supported a 1000 foot diameter circular screen of vertical wires located within the ring of monopoles. Due to their immense size, the location of the Bondville array ([40.0494° N 88.3807° W](http://stable.toolserver.org/geohack/geohack.php?pagename=Wullenweber&params=40.0494_N_88.3807_W_scale:2000)) and the other post-war Wullenweber arrays are clearly visible in high resolution aerial photography available on the internet.

In 1959, the U.S. Navy contracted with [ITT](http://en.wikipedia.org/wiki/ITT_Corporation) Federal Systems to deploy a worldwide network of AN/FRD-10 HF/DF arrays based on lessons learned from the Bondville experimental array. The FRD-10 at NSGA Hanza, Okinawa was the first installed, in 1962, followed by eleven additional arrays, with the last completed in 1964 at NSGA Imperial Beach, CA. (Silver Strand) A pair of FRD-10s not equipped for HF/DF were installed in 1969 at NAVRADSTA(R) Sugar Grove, WV for naval HF communications, replacing the NSS receiver site at the Naval Communications Station in Cheltenham, MD. The last two FRD-10 HF/DF arrays were installed in 1971 for the Canadian Forces in [Gander, Newfoundland](http://en.wikipedia.org/wiki/Gander%2C_Newfoundland) and [Masset, British Columbia](http://en.wikipedia.org/wiki/Masset%2C_British_Columbia). After the Hanza array was decommissioned in 2006, the Canadians now operate the last two FRD-10 arrays in existence.

Also in 1959, a contract to build a larger Wullenweber array -- the [AN/FLR-9](http://en.wikipedia.org/wiki/FLR-9) antenna receiving system -- was awarded by the U.S. Air Force to GT&E Sylvania Electronics Systems (now [General Dynamics](http://en.wikipedia.org/wiki/General_Dynamics) Advanced Information Systems). The first FLR-9 was installed at [RAF Chicksands](http://en.wikipedia.org/wiki/RAF_Chicksands) ([52.0443° N 0.389182° W](http://stable.toolserver.org/geohack/geohack.php?pagename=Wullenweber&params=52.0443_N_0.389182_W_scale:5000)), United Kingdom in 1962. The second FLR-9 was installed at [San Vito dei Normanni Air Station](http://en.wikipedia.org/wiki/San_Vito_dei_Normanni_Air_Station), Italy also in 1962. The Chicksands array was dismantled following base closure in 1996 and the San Vito array was dismantled following base closure in 1993.

A second contract was awarded to Sylvania to install AN/FLR-9 systems at [Misawa AB](http://en.wikipedia.org/wiki/Misawa_AB), Japan; [Clark AB](http://en.wikipedia.org/wiki/Clark_AB), Philippine Islands; Pakistan (never built); [Elmendorf AFB](http://en.wikipedia.org/wiki/Elmendorf_AFB), Alaska; and Karamursel AS, Turkey. The last two were completed in 1966. The Karamursel AS was closed and array was dismantled in 1977 in retribution for the suspension of U.S. military aid to Turkey. The Clark AB array was decommissioned after the Mt. Pinatubo volcano eruption in 1991. It was later converted into an outdoor amphitheater. As of 2007, only the Elmendorf and Misawa arrays remain in service, but both are likely to be decommissioned soon due to their age and unavailability of repair parts.

The U.S. Army awarded a contract in 1968 to F&M Systems to build AN/FLR-9 systems for [USASA Field Station Augsburg](http://en.wikipedia.org/wiki/USASA_Field_Station_Augsburg), Germany and Camp Ramasun in [Udon Thani Province](http://en.wikipedia.org/wiki/Udon_Thani_Province), Thailand. Both were installed in 1970. The Army version has the same design as the Air Force version, but the design of the delay lines in the Beam Forming Networks inside the Central Building are different. The Army used what is called a "Lamp Cluster" delay line design and the Air Force used a "Coaxial" delay line design. The Camp Ramasun array was dismantled in 1975 following base closure. The Augsburg array was turned over to the [Bundesnachrichtendienst](http://en.wikipedia.org/wiki/Bundesnachrichtendienst) -- the German Intelligence Service known as the BND -- in 1998, and it is no longer believed to be in service.

During the 1970s, the Japanese government installed two large Wullenweber arrays, similar to the FRD-10, at Chitose and Miho.

Later in the 1970s, [Plessey](http://en.wikipedia.org/wiki/Plessey) -- now [Roke Manor Research Limited](http://en.wikipedia.org/wiki/Roke_Manor_Research_Limited) -- of Great Britain developed their smaller, more economical Pusher CDAA array. At least 25 Pusher CDAAs were installed in many countries around the world. Several Pusher arrays were installed in U.S. military facilities, where the array is known as the AN/FRD-13.

Today, the Strategic Reconnaissance Command of the [German Armed Forces](http://en.wikipedia.org/wiki/Bundeswehr) operates a Wullenweber array in [Bramstedtlund](http://en.wikipedia.org/wiki/Bramstedtlund) with a diameter of 410m as one of its three stationary [Sigint](http://en.wikipedia.org/wiki/Sigint) battalions.