Book Review

Title: ***Big Ear Two – Listening for Other-Worlds***
Author: John D. Kraus
Publisher: Cygnus-Quasar Books
Date published: 1995
Availability: Available new from Radio-Sky Publishing (www.radiosky.com/booksra.html) for US$18.95 in hardcover. Also available on used book market (for example, www.abebooks.com) for a few US$ in paperback

I first heard of John Kraus in the late 1960s when I was an undergraduate electrical engineering student enrolled in a course called Fields, Lines and Antennas. Our professor was a fan of Kraus's helical antenna and had built a number of them for satellite tracking. However, it was not until 1973 that I obtained the famous book by Kraus called ***Antennas***. Most antenna book authors immediately drag out Maxwell's equations and proceed to provide very little practical information for those of us who like to actually build antennas. Kraus, on the other hand, packed his book with lots of practical information, and I was impressed. Kraus also is well-known for his book ***Radio Astronomy***, which has become sort of a bible for radio astronomers.

Forty years later, when I got involved in amateur radio astronomy, I heard about Kraus's ***Big Ear*** and ***Big Ear Two*** books and assumed they would be as well-written and informative as ***Antennas*** and ***Radio Astronomy***. I purchased the ***Big Ear Two*** (which turned out to be autographed) and overall I was not disappointed. One of the first things I look at in a book is the index. A weak index can ruin and otherwise good book. The index in Big Ear Two is almost 10 pages, but it contains mostly names of other radio astronomers – only about 1/20 of the entries are topics or key words. Still, as I was writing this review, the index was good enough to get me around so I guess I cannot squawk too loudly.

The subtitle "Listening for Other-Worlds" hints at some of the content. The book contains considerable discussion not of *other worlds* but *other-worlds*, the hyphen implying to me not the usual, pedestrian outer space but the more exciting other-worlds of intelligence (in the 1950s I was an ardent fan of science fiction movies and "other-worlds" were frequent themes). Indeed, ***Big Ear Two*** contains four chapters devoted to the search for extraterrestrial intelligence. I will return to these later.

I initially thought ***Big Ear Two*** was a book about the large but unconventional radio telescope nicknamed *Big Ear* that the author built near Delaware, Ohio. There is considerable non-technical discussion of this endeavor, but ***Big Ear Two*** really is a description of the author's technical activities throughout his life, and it covers much more than construction and use of this radio telescope.

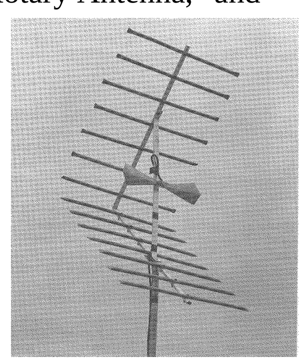
The front papers in my book copy contain plaudits by various reviewers. One of them says "*BIG EAR is 'an educational book for all ages. Recommended to all amateur astronomers'* . . . ." I agree. The book is easy to read. It has 33 chapters and is 370 pages long. It contains no mathematics at all and is worthwhile and interesting for its historic and entertainment value. It also reminds us that the problems of radio frequency interference (RFI) and ever-encroaching real estate developments are not new.

John Kraus's early days, described in the first six chapters were much like those of us who became interested in radio when young, from building crystal radio sets to using string and soup cans as a communication system. I initially was surprised how his youthful activities paralleled my own (although he was much older) but, once I thought about it, I remembered reading many accounts of radio engineers who did much the same thing. Although our paths as adults may have diverged (and Kraus became famous), our youths were very similar.

Kraus received his doctorate in 1933. He was an ardent amateur radio operator (call sign W8JK), which coincided with his interest in antennas and antenna design. He kept regular contact schedules with other radio amateurs throughout the world. In particular, he discusses schedules he kept with scientists working at universities in the US mid-west and west coast on "atom smashing" and high-energy physics. These included Ernest Laurence in Berkeley, California, and others, who used Kraus's amateur radios in the late 1930s to discuss their work. This was prior to World War II and there were no secrecy requirements.

Kraus's interest in amateur radio and antennas led him to build a "Bruce type" folded antenna, which was the same design used by Karl Jansky in 1932 when Jansky discovered extraterrestrial radio waves. Kraus's antenna was fixed with its main directional lobe pointed toward what at the time was the Belgian Congo. Kraus frequently helped a missionary there with messages to and from the home office. The success of the Bruce type antenna led Kraus to build additional antennas of the same type pointed toward Australia and other directions. Kraus also experimented with flat-top antennas that used close-spaced wires, which he called "Flat-Top Beam" because of its good directional characteristics.

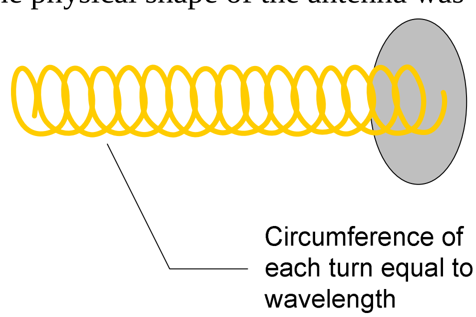
In the back of *Big Ear* Two, Kraus provides a chronological list of 146 articles he published. There was a succession of antenna articles in 1939 and 1940 in various magazines and proceedings on "Characteristics of Antennas with Closely Spaced Elements," "The Square-Corner Reflector," "Multi-Wire Doublet Antennas," " Compact H-Beam Antenna," "Twin-Three Flat-Top Beam Antenna," " Multi-Wire Dipole Antennas," "Three Band Rotary Antenna," and many more. All of these articles were written for radio practitioners and were the result of Kraus's experimentation. Kraus often took notice of other people's antenna designs and then went to work improving them with experimental and theoretical considerations. He invented the helical beam antenna in 1947, and it subsequently became probably the single most often-used antenna type in the US space program. He also conceived the corner reflector antenna (right, from chapter 9), versions of which can be seen on residential rooftops for television reception. He was an experimenter of the first kind. I wonder if those early articles are available somewhere.



In 1940 Kraus went to work at the Naval Ordnance Laboratory (NOL) at White Oak, Maryland. A fellow engineer at NOL was Grote Reber, an early radio astronomy pioneer. Kraus worked at NOL until 1943 on mine countermeasures for allied navy ships. The ship's large steel structures would become magnetized through normal operations and set off nearby enemy mines that used magnetic sensing. As a countermeasure, the NOL developed de-magnetizing (degaussing) coils for the ships, and one of Kraus's jobs was to test the installed coils and their effectiveness at a measuring range in Chesapeake Bay not far from the NOL headquarters. A sign on his desk said "Degauss with Kraus." During this work he became frustrated by the poor communications between the ship used for measurements and the ships being measured. The navy used blinker lights to send Morse code, a method that was slow and error-prone especially during bad weather and low visibility. One time Kraus had to use his hat to flash a car's headlights to get the attention of a ship he needed to visit. When he tried to improve the situation by suggesting radiotelephones, in typical US Navy fashion, Kraus was told "*Blinker lights are what we use when we are within visual range of other ships. Radio isn't practical.*" Nevertheless, Kraus and his section at NOL moved forward and developed a 300 MHz radio transceiver that worked very well and eventually was accepted by the Navy for the testing.

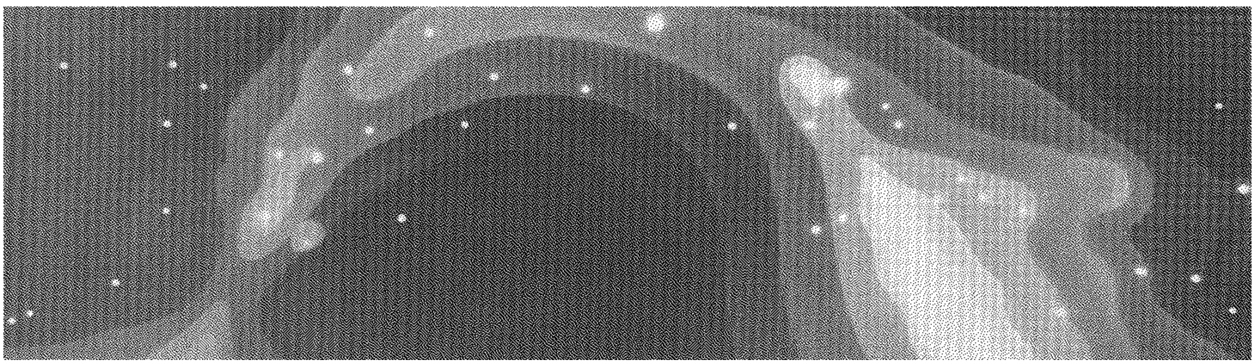
In 1943 Kraus moved to the Radio Research Laboratory (RRL) at Harvard University to work under Frederick E. Terman on radar counter-measures (radar jamming). Terman was from Stanford University and even today is well-known among radio engineers for his practical books and handbooks (now long out of print but still very useful). There was a roof fire at RRL one day but firemen were not allowed in the building to fight the fire because they did not have security clearances. Eventually, they were admitted one at a time with a security guard assigned to each fireman. Some of the radar jammers designed by RRL were very powerful and, as Kraus said, "could fry you a block away! It was a real 'people cooker'." When the war ended, Kraus went from researcher to author and helped write a 2-volume set of books for RRL called ***Very High-Frequency Techniques***.

Ohio State University (OSU) in Columbus, Ohio hired Kraus in early 1946 and while there he invented and developed the helical beam antenna (right). The physical shape of the antenna was conceived by Harold A. Wheeler as an antenna for circular polarization. However, the dimensions of Wheeler's antenna were such that it had a broad radiation pattern from the side and not a narrow pattern along the axis like Kraus's antenna. Whereas the helix diameter in Wheeler's antennas is very small compared to the wavelength of operation, the Kraus's helix has a circumference equal to the wavelength. This made all the difference in the world.



Kraus relates one incident at OSU that was (and probably still is) repeated time and again in the science and research industries but is shocking nonetheless. A female graduate student had applied for study and was interviewed by professors from the electrical engineering department. When she entered the room for the interview, the chairman, in a rude display of male chauvinism, turned his chair around so his back was toward her. He refused to speak to her. Kraus had to take over as chairman and proceed with the interview. It turned out she was well-qualified and was admitted to OSU's graduate program.

Before long Kraus started thinking about a radio telescope and planning to build one. Money was not easy to come by but he was granted US$2,000, which he figured would buy 10 tons (20,000 lb or about 9,100 kg) of steel for the antenna framework – I will leave it to the reader to figure out how much steel US$2,000 will buy today. He used helix antennas made from 11 turns of 1 cm diameter aluminum tubing. Each helix was about 2 m long and 30 cm in diameter. By 1952, he had built an array of 48 helices and put them into operation. At that time, OSU was one of three universities in the USA with a radio telescope. Kraus was granted additional money for his radio astronomy research and added another 48 helices to his array, for a total of 96. This array unofficially was the first "*big ear*" and was in steady use by 1954. One result of Kraus's early radio astronomy work was a radio sky map at 250 MHz (below, from chapter 14) and another was a catalog of over 100 previously undiscovered celestial radio sources. The second big ear, which Kraus called a "*really big ear*", was a much more ambitious project and followed several years later.



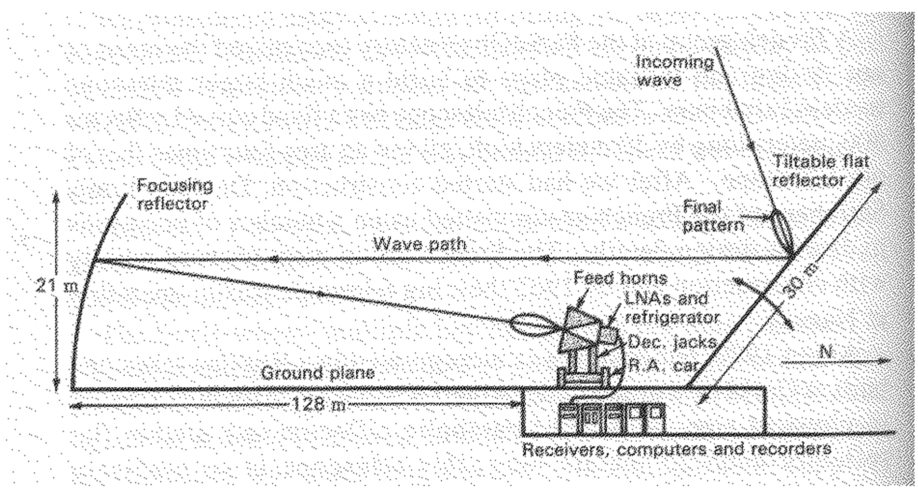
The success of the 96-helix array radio telescope got a lot of people fired up about radio astronomy in the USA, including Kraus, and by 1956 he was ready to build a bigger radio telescope. Readers of the ***Big Ear Two*** are almost one-half finished with the book at this point, and from this point forward, Kraus is involved almost 100% with radio astronomy. He completed his books ***Antennas*** in 1950 and ***Electromagnetics*** in 1953. His book ***Radio Astronomy*** would be published in 1966. The second editions of all three books would be issued in the 1970s and 1980s.

Kraus began designing and building the new radio telescope in 1956 but he was pushed off course by international events. In the late autumn of 1957, the Russians launched Sputnik 1, the first Earth-orbiting artificial satellite, causing a worldwide stir and a panic in the US government. The Russians followed a few weeks later with Sputnik 2. Many people with shortwave receivers tried to hear the Sputnik 1's 20 MHz transmissions. Kraus was among them, and he was successful. He noted that "*The U.S. had spent millions probably billions of dollars, building a DEW (Distant Early Warning) line with huge radar antennas all across the Canadian arctic to warn of the approach of Russian aircraft coming in over the north pole. In one stroke the DEW line was obsolete.*" Well, I do not think it actually was obsolete, for it remained in service until the early 1980s, when the system was upgraded with new minimally attended radars (MAR) and fewer sites. A modern version of it still is in service today. The original DEW line actually covered all of northern Alaska (in addition to northern Canada) with additional radar warning stations along the Alaska Peninsula and Aleutian Islands. I visited many of the stations in the late

1950s and early 1960s and was given a tour of the Cold Bay station on the peninsula by the site commander in 1958.

Kraus tried an interesting experiment while the Sputniks were orbiting the Earth. The satellites were low Earth orbit types (altitude 223 x 1,450 km above the surface), and Kraus figured that as the satellites traveled through the ionosphere, they might disturb or bunch the charged particles, "*like a golf club driving a ball*," enough to permit reflection of HF radio waves at night. The ionosphere is considerably thinner at night because there are no high-energy ultra-violet rays from the Sun to strip electrons from the atoms and molecules that make up the Earth's atmosphere. This disturbance or bunching became known as the "Kraus Effect". He made recordings and wrote that "*There did seem to be bursts of WWV* (US time and frequency station) *signals during the night after it had faded out which were near the expected times for passes of Sputniks 1 and 2. The bursts were much stronger and much longer than those due to meteors.*" Here he makes reference to the ionized trails of meteors (these were noticed by James S. Hey on England defense radars in 1943[1]). Meteor trails can be detected by amateur radio astronomers using simple setups involving, for example, an ordinary FM receiver and outdoor antenna.

Kraus continued these types of studies on Sputnik 3 and Echo 1, an early US communications satellite that operated as a passive reflector. Kraus states in reference to the recently (at that time) discovered Io-enhanced emissions from Jupiter "*It appeared to us that the satellite-induced ionization effects and the 'Io effect' were actually different aspects of the same phenomenon.*" What is interesting about the satellite-induced ionization studied by Kraus is that it might be used to detect enemy satellites undetectable by radar or optical means. The US Department of Defense was interested in this aspect and it is resulted in the construction of the huge 305 m radio telescope in a natural mountainous bowl at Arecibo, Puerto Rico. [2]



After being deflected by the Sputnik events Kraus was able to continue work on the new radio telescope at OSU, and he starts an extended discussion of it in chapter 18 (Big Ear). The *Big Ear* radio telescope uses an unusual antenna consisting of two large reflectors, one flat and the other curved for focusing (above-right, from chapter 18). Between the two reflectors was a huge ground plane made from aluminum sheet. Its dimensions were 360 ft wide by 500 ft long (110 m x 152 m). The flat reflector was built in sections totaling 340 ft long by 100 ft wide (104 m x 31 m) and

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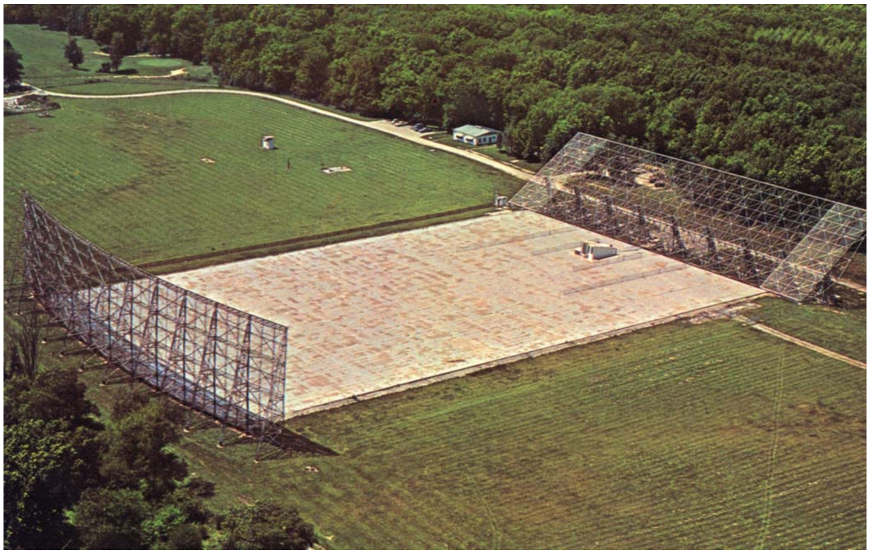
[1] See my review of Hey's book ***The Evolution of Radio Astronomy*** in the October/November 2010 issue of the SARA Journal

[2] Arecibo antenna at 18° 20' 38.84"N : 66° 45' 09.82"W

could be tilted to adjust the elevation angle. The curved focusing reflector was shaped like a section cut along a hollow sausage, but its shape was parabolic in two dimensions. The dimensions were 360 ft long by 70 ft high (110 m x 21 m). Kraus had spent much time calculating the best cost-performance tradeoffs and finally settled on these dimensions. He designed it to be built in small, manageable sections so that no special construction equipment or methods were required.



Kraus received grants from the US National Science Foundation (NSF) and from the university and built the radio telescope almost completely with student labor over a period of several years. Electrical engineering students with welding experience were preferred. By 1960 the flat reflector was finished and by 1963 enough work was done on the remaining radio telescope components that Kraus was able to start an observation program (above-right, used with permission of Big Ear.org). One result of these observations was a radio map of the Andromeda galaxy that showed its radio size to be much larger than seen in optical photographs. Larger versions of Kraus's *Big Ear* antenna were built at Nancay, France and Zelenchukskaya. Russia.[3]

Chapters 18 through 22 describe the problems and impressive progress and contributions that Kraus and his students made to radio astronomy. One chapter includes some discussion on the structural failure and collapse of a portion of the flat reflector due to inadequate specification and design of the winches used to tilt it. Another describes radio frequency interference (RFI) from military airborne radar jammer training, satellites, land developers and farm tractor ignition systems and how all these problems were resolved.

The size of the OSU celestial radio source catalog continued to grow through a series of *Installments* and by the beginning of 1972, Kraus's group was a year into Installment VI. However, later that year NSF stopped funding the *Big Ear*. The NSF had started to move toward funding national facilities like those of the National Radio Astronomy Observatory, NRAO, and university facilities were not part of their plan. Data reduction for Installment VI of the catalog was finished in early 1974 with over 6,000 new celestial radio sources. The total of all installments so far was over 17,000, covering most of the sky observable from Ohio. Loss of government funding did not immediately end Kraus's sky survey work. In autumn of 1972 he started the 7th and final installment of the Ohio Sky Survey, which was completed in mid-1973.

[3] Nancay antenna at 47° 22' 14.09"N, 2° 11' 50.66"E and Zelenchukskaya antenna at 43° 49' 33.49"N, 41° 35' 11.61"E

Data reduction was finished in late 1974 bringing the total number of celestial radio sources discovered by the *Big Ear* to 19,000.

With the *Big Ear* and discoveries enabled by it, Kraus began to ponder whether or not man is alone in the universe: "*Big Ear is a large radio telescope designed as a search instrument. With it we discovered thousands of radio sources during the Ohio Sky Survey. It is equally well-suited for a search of signals from other civilizations and had, in fact, been used for just that.*" Kraus spends all of chapters 23 (Is Man Alone?) and 24 (The Search) discussing the problems associated with contacting and communicating with extraterrestrial civilizations. One example he gives goes as follows: Say a civilization advanced enough to communicate is in a galaxy 1,000 light years away. A radio message would take 1,000 years to reach them and their reply would take another 1,000 years to reach us, for a round trip delay of 2,000 years. There clearly would be no opportunity for dialog, and all such communications would really be monologues to say nothing of language translation problems.

The *Big Ear's* search for extraterrestrial intelligence (SETI) began in late 1973 and ran 24 hours per day, 365 days per year for 4 years, when on August 17, 1977 the *Big Ear* computer printed at 12 second intervals the sequence "6, E, Q, U, J, 5" from one of the radio channels. These numbers indicated the signal strength above the noise background in a scale of 1 to 9 followed by A, B, C, and so on. An analyst wrote "Wow!" on the chart. However, they only knew the "signal" was "*a fleeting narrow-band signal on 1420.356 megahertz (channel 2) at a sky position of 19 hours 22 minutes 22 seconds right ascension and 27 degrees 3 minutes south declination referred to epoch 1950.0"*. For a while, the SETI was funded by the US government but that was killed in 1992.

Among his many activities, Kraus edited and published a SETI magazine called ***Cosmic Search***. The first run of 65,000 complementary copies was sent out with the hope that subscriptions would fund the magazine from there on. However, only a relatively small number of subscriptions were received and Kraus, wishing to continue, paid all the magazine expenses out of his own pocket for the next three years. A total of 13 issues of Cosmic Search were published between 1979 and 1982.

The *Big Ear* radio telescope was not on land owned by OSU. The land belonged to a neighboring university and was being used for the OSU radio telescope under a cooperative agreement. As with almost all such deals, the principals involved eventually move on, retire or die, and the new administration's priorities are different.

Although Kraus fought hard to keep the *Big Ear* in operation and had support from many colleagues, it was not enough. The *Big Ear* ceased operating in late 1997 after 34 years and was torn down in 1998 to be replaced by a golf course and housing development. The current land use can be clearly seen in satellite imagery[4] and the only trace of the *Big Ear* is a historical marker[5]. A website is dedicated to the *Big Ear* radio telescope, and it includes all issues of Cosmic Search magazine.[6]

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[4] Big Ear was located very near 40° 15' 4.34"N : 83° 3' 6.24"W
[5] http://www.bigear.org/ohsmarkr/markermenu.htm
[6] http://www.bigear.org/

The last few chapters of ***Big Ear Two*** are short, introspective and philosophical and seemed to me to be quite different from the previous chapters. John D. Kraus died at the age of 94 in July 2004.

Whitham Reeve was born in Anchorage, Alaska and has lived there his entire life. He became interested in electronics in 1958 and worked in the airline industry in the 1960s and 1970s as an avionics technician, engineer and manager responsible for the design, installation and maintenance of electronic equipment and systems in large airplanes. For the next 38 years he worked as an engineer in the telecommunications and electric utility industries with the last 33 years as owner and operator of Reeve Engineers, an Anchorage-based consulting engineering firm. Mr. Reeve is a registered professional electrical engineer with BSEE and MEE degrees. He has written a number of books for practicing engineers and enjoys writing about technical subjects. Since 2008 he has been building a radio science observatory for studying electromagnetic phenomena associated with the Sun, Earth and other planets.