JINDALEE OVER THE HORIZON RADAR & OTH RADAR IN CHINA, RUSSIA & FRANCE.

(Prepared by R W Madsen August 31, 2018)

INTRODUCTION.

The conditions in the ionosphere over the Sydney region of Australia was the principal subject of research by J P V Madsen with the Radio Research Board during the 1930's (see 2 images-Macrossan Lecture & diagram of Ionosphere radio transmissions below) & it was this work which lead directly into the Australian radar developments of WW2 under the auspices of CSIRO. In the post war period, radar & other scientific developments for the military in Australia were taken up by the DSTO. The application of reflection of radio waves of metre wavelength by the ionosphere & returned as "backscatter" to a receiver is a very remarkable achievement & has been taken up by quite a few countries, including China. The Doppler principle is used throughout with OTH radars. The metre length radar waves apparently have the ability to "wrap around" an aircraft such as a stealth fighter & return an observable radio wave.

A significant upgrade to Jindalee is to be made incorporating the Sapphire clock, (see image below) developed by the University of Adelaide, & several other improvements. The 5 cm cylinder shape of the sapphire crystal resonates at one particular frequency resulting in an extremely low loss of energy & the improved accuracy of timing in Jindalee involves factors of up to 1,000, & far greater resolution of smaller targets is expected at greater ranges.

In China at least 3 OTH Radars have thought to become operational & integrated into their radar network where radar interferometry is used to obtain accurate positioning of targets by triangulation, all within a similar coverage as Jindalee. (see image below). The possibility of ECM (eg. jamming) by China on Australian OTH-R, should they consider it necessary, cannot be overlooked.

In Russia there currently appear to be both a long range (3,000 km) OTH-R ["Kontayner" – "29 B6"] (see coverage image below) & a short range (500 km) system ["Sunflower"].

France is noted for having a 360 degree omnidirectional OTH-R ["Nostradamus"-see image below] with a detecting range of 800-3,000 km & also a Surface Wave HF radar operational on the French Mediterranean coast out to 200 nautical miles in all climate conditions ["Stradivarius"].

In 2015 a joint US-British-Canada-German project reportedly tested a quantum radar with a "potential" range of only 20 kms however Canada is doing further work to try & obtain an " on demand" source of photons to be used in a radar in Arctic regions which are affected by electromagnetic phenomenon such as auroras & solar flares.

OTH Radars during the Cold War.

By the end of the Cold War in 1991 most of the OTH-R radars in the US & Russia were shut down. The antenna on these radars were typically very large & heavy structures quite different to the parallel rows of vertical free standing poles. In the US, the Navy did retain OTH radars covering the Caribbean & Central America for drugbusting purposes rather than military ones.

In the UK at Orfordness, Suffolk (location of Watson-Watt & Taffy Bowen's pioneer radar set in 1935) a joint Anglo-American high powered OTH radar ["Cobra Mist" –AN/FPS-95; see coverage image below]

was built between 1966-1971 at great cost but was shut down in 1973 as it was plagued by noise problems which could not be traced, although Russian ECM (Electronic Counter Measures) had not been ruled out. The power was a massive 10 MW broadcasting on 6-40 Mz frequency with a range 930-3,700 km over an arc from 19.5 to 110.5 degrees. There were 12 towers (5 at 340 feet) with 18 individual strings radiating out from a point near the Orfordness shore, each string being 620 metres long. The reflection was at the F layer of the ionosphere (the Appleton layer with the highest density of electrons).

US NAVY- 3 Relocatable OTH –R covering drugbusting surveillance.

The 3 stations ,directed south, are in Virginia (1993) Texas (1995) & later in Puerto Rico were relocatable in the sense that the receiving & transmitting antenna were fixed with the cabling as well, but the transmitter, receiver & control unit could all be relocated. The features of these sets probably give some indication of how Jindalee operates & involve 12 Dwell Illumination Regions for surveillance at any one time with any one DIR for up to 49 seconds; time is shared for simultaneous tracking of ships & aircraft. The system is largely automatic with an operations control centre either co-located or separately with a satellite link configuration. The transmit & receive antenna are 92-185 km apart with coverage 64 degrees wide in the illuminated sector. The receiving array has 372 twin monopole elements covering approximately 2.58 km.(see image below). Wavelengths are 10-60 metres with Doppler processing for moving targets, & frequencies adjusted with changing ionospheric conditions detected by quasi – vertical incidence sounder. Raytheon maintains the system, Power is 200kw with frequency range 5-28 MHz.

Australian Jindalee OTH-R .

The lead up work for the Jindalee project started in the 1950's looking at the difficult physical principles & engineering involved with an OTH-R back scatter radar. In 1969 visits were made to the US to speak with OTH-R people there & this co-operation has continued to the present day in the form of Raytheon & the 3 US Navy ROTH-R radars covering the area south of the US for drug busting work. Jindalee became operational with the RAAF in 2003 & currently has 3 stations located near Alice Springs, Longreach & Laverton (WA) with a nominal range of 3,000 km covering an area of 13 mil. Square kms (1.7 times the area of Australia) over the north of Australia, New Guinea, Java & the Celebes. Alice Springs & Longreach have 90 degree coverage, whilst Laverton has 180 degree coverage; the Control Centre is at Edinburgh SA. The radars can be aimed at any particular location a search is required in the shape of a "tile" or "search box"-there is digital transmission of data after analogue conversion from the antenna. Current resolution of Jindalee is not sufficient for weapons fire & surface targets the size of an Armidale Class patrol boat is approximately the smallest size of boat that can be detected & only within a range of 2 km. The 2-30 MHz receivers have been supplied from Germany by Rohde & Schwarz GmBH;-the receive antennas for Laverton & Longreach are free standing pairs but for Alice Springs they are guyed structures.(In 1997 it is reported that Jindalee detected a missile launch in China at a range of 5,500 kms.)

The Phase 6 upgrade of Jindalee is considered to be a revolutionary step forward & besides the Sapphire Clock (reminiscent of Lord Rayleigh's 1878 discovery of the "whispering gallery" concept in St Pauls cathedral) there are changes to have an open system architecture to allow insertion of next generation technologies, ultra low noise synthesis technology & signal dissemination technology.

It should be mentioned that Australia (La Trobe Uni & Uni of Adelaide) has 3 HF [8.00-22.0Mhz] radars of low power [Bruny TAS, Unwin Invercargill NZ & Buckland Park SA] directed as pairs over the southern polar regions to monitor the location of aurora & related phenomena occurring in the Ionosphere 100-300 km above earth.(TIGER-Tasman International Geospace Environment Radar, part of a 10 nation programme in both the northern & southern hemisphere to provide simultaneous coverage-).

QUANTUM RADAR –CANADA.

A quantum radar functions by using a crystal to split a photon into 2 entangled photons, then the radar beams one half of the entangled pair outwards & monitors the corresponding effects on their entangled partners. If the beamed particles bump into say a stealth fighter, the effect on the beamed photon would be visible on the un –beamed photon as well. The photons which register a "ping" are sorted out from the unaffected photons to form a sort of radar image. The advantage of a quantum radar is that it would not be detectable & does not broadcast its presence, but on the other hand entangled particles do eventually lose the coherence of their quantum state over long distances & adverse weather. These distances may be as short as 20 kms as found in the West in 2015 but may be longer as China claims in 2016 (100 kms, 2017-1,000 km satellite connection), in any event Canada , at the University of Waterloo, is looking into it further to first meet the need for an on-demand source of photons ie. a robust source of entangled photons. The Canadian interest is in regard to the replacement of the radar North Warning System in 8-10 years time currently served by 54 radars covering 4,800 kms long by 320 kms wide at the 69 th parallel. The advantage of a quantum radar for Canada would be that they would be unaffected by electromagnetic phenomena common in the Arctic, such as auroras & solar flares.

OTH-R in China.

It would appear that China has a very large network of radars along her coast line integrated through a control centre to co-ordinate data from satellites as well as a number of OTH-Backscatter & Surface Wave radars. Sky wave OTH systems have been reported in use since 2005 & currently their Tianbo system appears to be located in Inner Mongolia, Hubei province, Heilongjiang province to the north & Guangzhou province to the south. A range of 3,000 km easily covers Japan & South Korea to the east & the Malacca Straits to the south. A combination of skywave & ground wave OTH's are believed to be used with radar interferometry (as per Joe Pawsey – ie. an exponential increase in radar power) to very accurately give complete coverage out to a range of 3,000 kms. Frequencies have not been disclosed but a radar enthousiast in California in the Mojave Desert reported in 2013 signals on 5,835 Khz (also China often disturbs 7,080-7,130 Khz) suggesting they use the same frequencies as Aust. The Chinese claim to be able to detect within 60 seconds a launched ballistic missile against them. It has been noted that a HF radar (surface wave) may have been installed at Cuarteron Reef & also Fiery Cross in reclaimed islands of the Spratleys projecting the Chinese militarisation into the South China Sea.

Of particular note is the leading Chinese scientist Qian Xuesen (1911-2009) who was involved in all manner of Chinese rocketry & other projects after his return to China in 1955 after having been at MIT & Caltech (JPL startup). Deng Jiaxian (1924-1986) is also remembered for his leading role in the Chinese nuclear programme having graduated with a PhD from Purdue University in 1950.

China's quantum applications appear to involve both satellite communication & radar. China launched a Micius satellite as a proof of concept for China's global quantum satellite communications network proposed to be up by 2030, however Germany has apparently demonstrated that existing

communication satellites could be used to transmit quantum information such as encrypted financial data which threatens to render current methods of encryption obsolete.

In August 2016 China claims to have achieved a 100 km range with a working quantum radar.

OTH Radar in Russia.

Russia currently appears to have a long range OTH-R ("Kontayner" or "29B6") & a short range system ("Podsolnukh-E" or "Sunflower"). The coverage of "Kontayner" out to 3,000 km heading west from the transmitter south of Moscow is shown in the attached diagram-operating in the 3-30 Mhz range & a power of 10 MW. The Sunflower system appears to have a range of 500 km & in Russia is currently located in the Crimea looking to the Bosphorous, the Caspian Sea & the Sea of Okhotsk towards the Sea of Japan. Russia has plans to militarise the Arctic region & 6 OTH systems are proposed for the Russian Arctic region. In the Cold War period Russian OTH radar become known as the "Russian Woodpecker" by shortwave enthousiasts over many years, but this completely stopped by 1989.

French"Nostradamus" OTH radar.

The French "Nostradamus" OTH radar is located at Dreux, 100 km west of Paris & has a detecting range of 800-3,000 km with 360 degrees of coverage. The system was built with off the shelf components in the late 1990's & has 288 emitting & receiving antennas in a star configuration giving precise tuning of the elevation beam & omnibearing surveillance getting a targets elevation angle, azimuth angle, ground co-ordinates & ground range. The control centre & equipment is located underground. The system is monostatic with signals transmitted & received at the same location.

Since 2015 France also has a Surface Wave OTH radar "Stradivarius" operational on the French Mediterranean coast for surveillance of the Gulf of Lyon with the maritime approaches out to 200 nautical miles from the coast in all climate conditions.

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JOHN MURTAGH MACROSSAN LECTURES
1935

THE IONOSPHERE

AND ITS

INFLUENCE UPON THE PROPAGATION OF RADIO WAVES

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SYDNEY: SIMMONS LIMITED
1935

MEETS

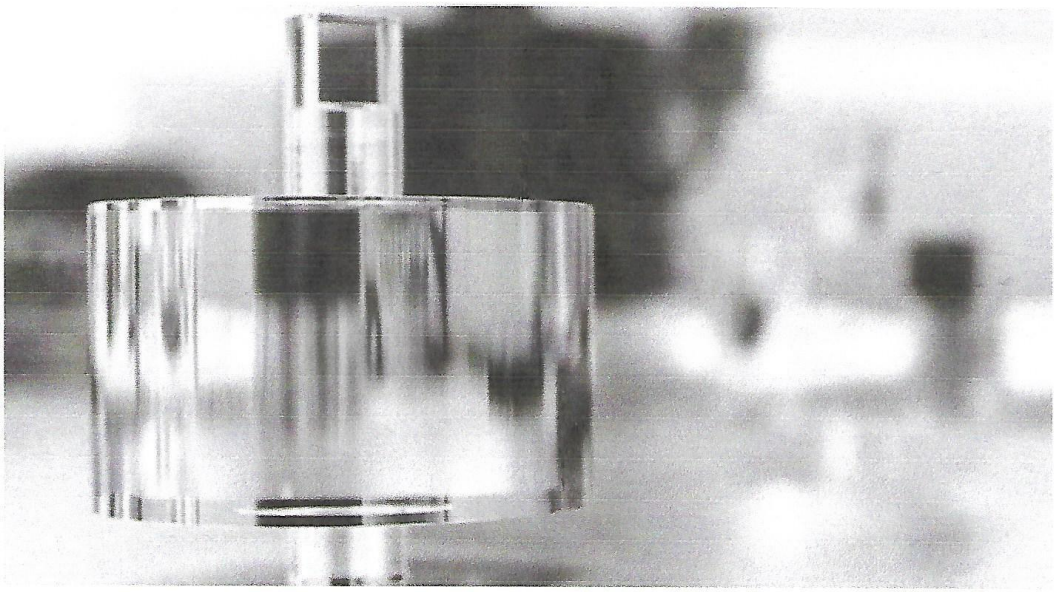
NEWS AT THE NEXUS OF RESEARCH AND INDUSTRY

(http://sciencemeetsbusiness.com.au/)

Sapphire Clock ticks towards the attosecond

October 28, 2016

The world's most precise clock has been fine-tuned to boost radar and GPS capabilities.



Featured image above: the sapphire crystal used to make the Sapphire Clock on display at the University of Adelaide. Credit: University of Adelaide

The Cryogenic Sapphire Oscillator, or Sapphire Clock, has been enhanced by researchers from the University of Adelaide (http://www.adelaide.edu.au/) in South Australia to achieve near attosecond capability.

Fig. 1. Nostradamus Array

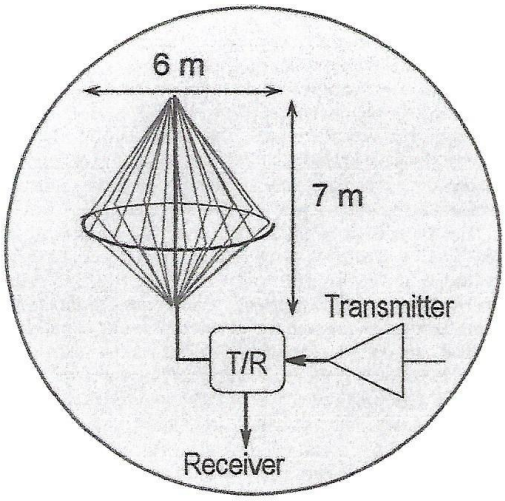


Fig. 2. Biconical Antennas

Each arm is near 400 meters long. The antennas are randomly distributed on 80 meters width along the arms. The elementary antenna is a biconical one (7 meters high × 6 meters width) with an omnidirectional pattern in azimuth (Figure 2).

The array association as a star allows all azimuth coverage and the control of the beam in elevation. The employment of large antennas requires the use of a metallic ground plane to reduce the VSWR, voltage standing wave ratio.

One part of antennas is used for transmitting and the whole array for receiving (Figure 3). It is possible to smultaneously form narrow receiving beams in the two dimensions azimuth and elevation in the footprint of the wide transmitting beam.

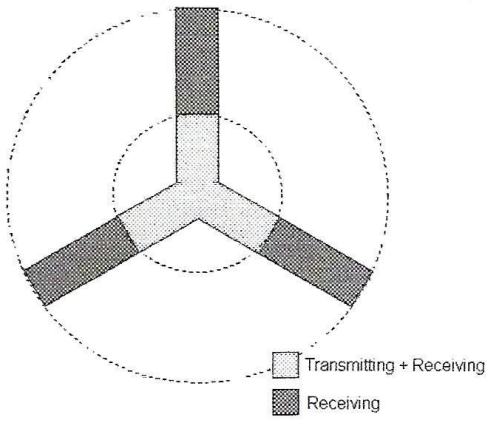


Fig. 3. Repartition between transmitting + receiving antennas and receiving antennas

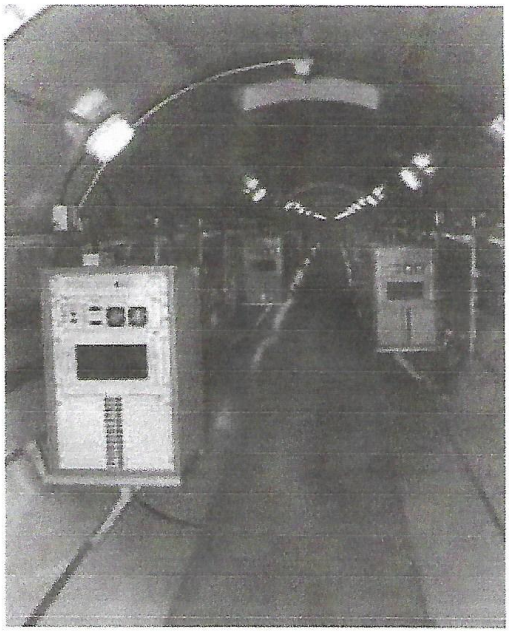


Fig. 4. Technical Tunnel

1) Transmitting System

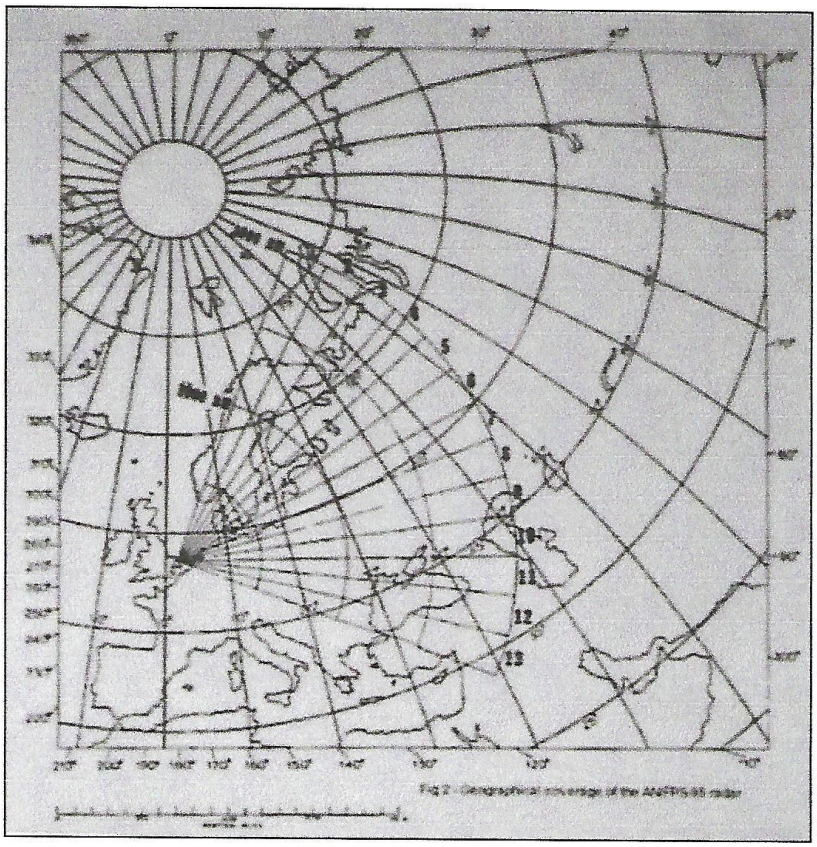
One hundred transmitters associated to each transmitting antenna, constitute the transmitting system of NOSTRADAMUS radar. They are installed in underground technical tunnels under each arm of the array (Figure 4). Each

Middle East and the Arctic. The radar can track all airborne targets (including planes, helicopters, drones and cruise missiles) and objects in space.

The 29B6 is a bi-static radar system, with separate transmitters and receivers located far away from each other. The transmitter antenna is 440 m long and includes 36 components; it is located in Nizhny Novgorod (250 km east of Moscow). The 29B6 receiver antenna is in Kovylkino (150 km south of Nizhny Novgorod) and has 35m-high pylons spread out over 1.3 kilometers. The 29B6 radar system is far more advanced than the "Duga" family, working in wavelengths in the range of 10–100 m (3–30 MHz frequency).

Most military detection and fire control radars (land, sea or air) operate in the centimeter and millimeter range. Since waves from centimeter and millimeter radars are sent parallel to the ground, they cannot pass barriers in the relief. These radars are limited in performance by the curvature of the earth to a range of 300–450 km maximum.

In contrast to the centimeter and millimeter radar range, short wave radars like the 29B6 emit pulses at an angle of inclination up to 45 degrees from the ground. They are repeatedly bounced off the ionosphere to look beyond the horizon without significant loss of signal. This ionospheric refraction gives the radar an optimal zone for detection of aerial targets in the range of 400–4000 km from the




U.S. Navy ROTHR
2.6-km Receiving Array

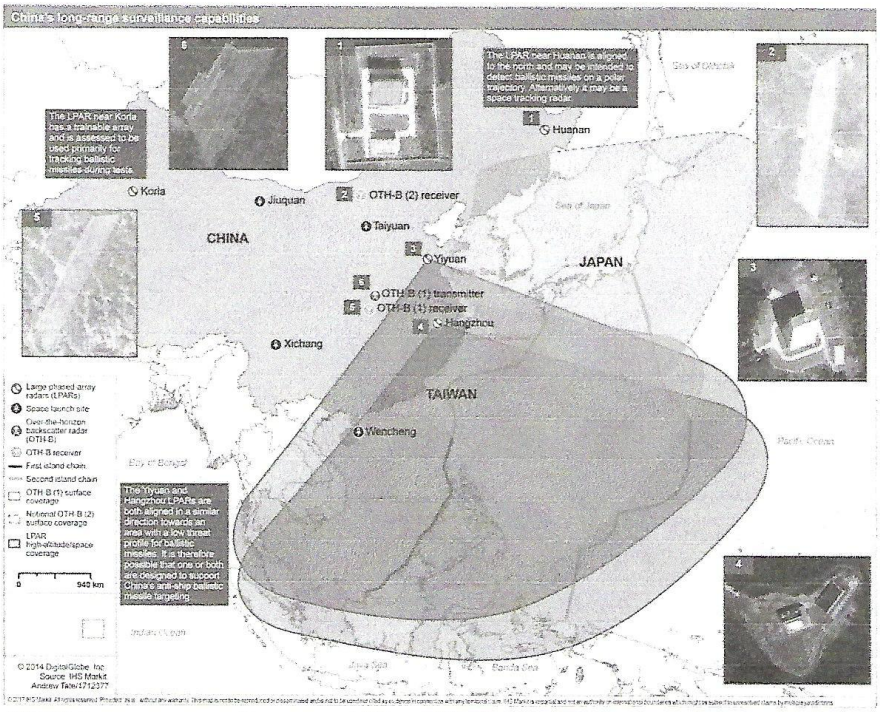
Jane's
By IHS Markit

China integrates long-range surveillance capabilities

[Content preview – Subscribe to **Jane's Intelligence Review** for full article]

As China seeks to expand its control over its maritime approaches and to operate further afield, it has developed its space- and ground-based long-range surveillance capabilities. *Andrew Tate* looks at these assets and considers the capabilities that they deliver.

On 29 September, a Long March 2C rocket was launched from China's Xichang Satellite Launch Centre, carrying three Yaogan surveillance satellites. These are further additions to China's array of long-range surveillance assets, which has increased and improved dramatically since 2006.



China's long-range surveillance capabilities. (IHS Markit)

1712377

China has a strategic need for surveillance of its seaward approaches for national defence and to underpin its goal of exerting sea control in its exclusive economic zone (EEZ), which would expand vastly if China's claims in the South China Sea were to be established. Geography does not favour China, as the air and sea routes to the open waters of the west Pacific are obstructed by the 'first island chain', which includes the Japanese archipelago, Taiwan, the northern Philippines, and

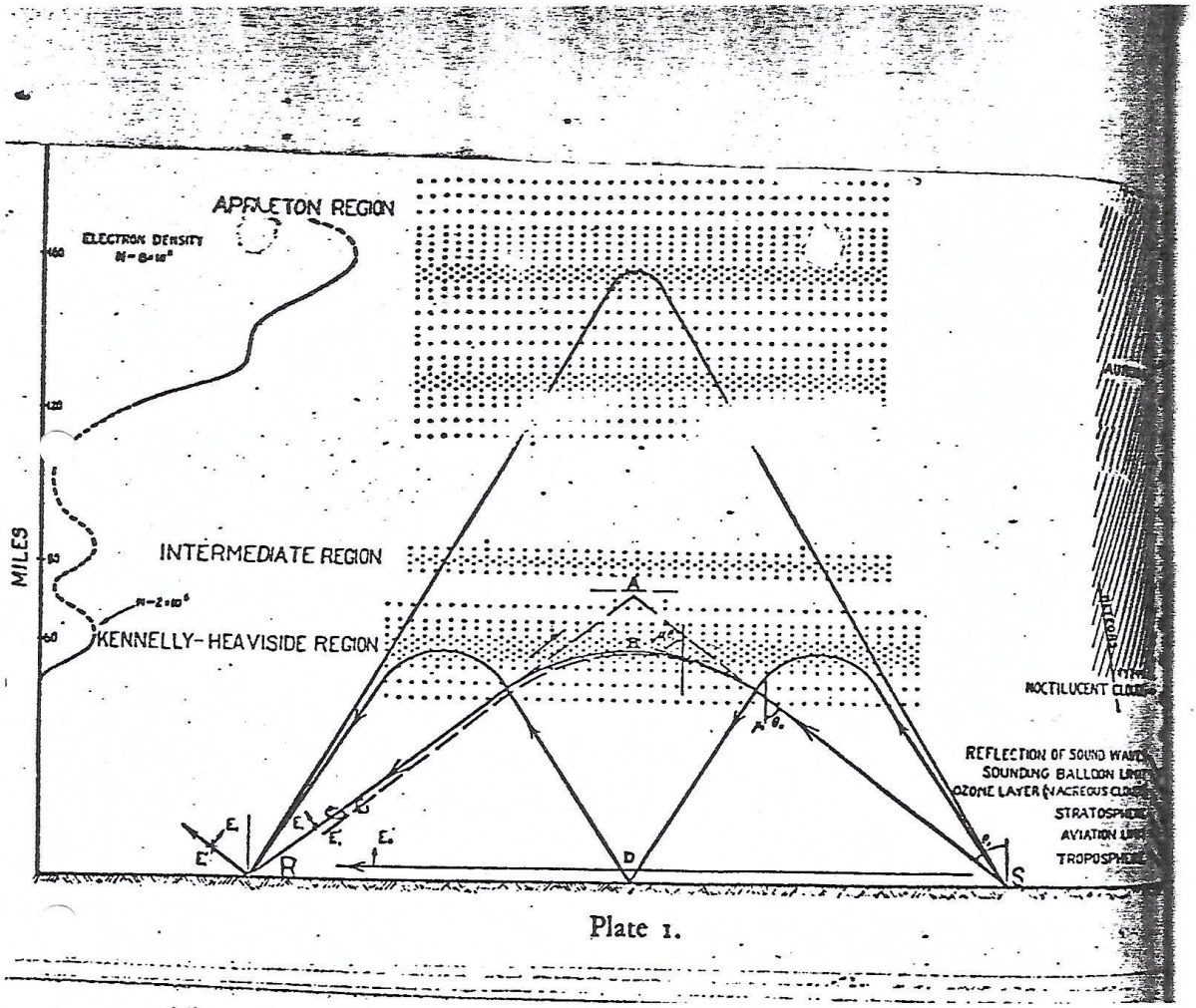

APPLETON REGION
ELECTRON DENSITY
INTERMEDIATE REGION
KENNELLY-HEAVISIDE REGION
MILES
NOCTILUCENT CLOUDS
REFLECTION OF SOUND WAVES
SOUNDING BALLOON LIMIT
OZONE LAYER
STRATOSPHERE
AVIATION LIMIT
TROPOSPHERE
A
B
C
D
R
S

Plate 1.