5.13A DESIGN CONSIDERATIONS OF A PROPOSED UK VHF RADAR

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The proposal that a VHF radar should be established in the UK as a national facility for the study of the dynamics of the middle atmosphere was first submitted to the SERC in 1980 by Sir Granville Beynon and others from ICW, Aberystwyth. As part of the subsequent evaluation of the proposal, a discussion meeting attended by about 50 scientists was held at the Royal Society on 30 September 1981 and it was agreed at this meeting that a more definitive version of the Aberystwyth proposal should be prepared by Professor L. Thomas (who succeeded Sir Granville Beynon at UCW on 1 October 1981) and submitted to the Solar System Committee at its meeting on 2 December 1981. At that meeting the Committee, after considering the report prepared by Professor Thomas, approved the carrying-out of a design study at RAL and appointed Professor Thomas as the Project Scientist.

The timeliness of the proposal that the UK should construct an MST radar can be gauged from the fact that at the present time different atmospheric radar systems already exist or are being planned, upgraded or constructed in nine different countries. During the last few years the international scientific community has identified middle atmospheric studies as an important branch of geophysics -- hence, for example the Middle Atmosphere Programme being carried out under the auspices of SCOSTEP. Work in this field is likely to be particularly fruitful, especially if it is based on data obtained using the MST radar technique which is now widely recognized as one of the most powerful ways of studying the atmosphere right from the Earth's surface into the mesosphere.

The provision of an MST radar in the form of a national facility open to any member of the interested community (which is already of a significant size, but which is expected to expand once the radar becomes operational) would constitute an important step in the progress of atmospheric science in this country; if the radar is not forthcoming, however, the UK will be left outside one of the mainstreams of international geophysics.

One of the most difficult aspects of providing a radar as a central facility for any or all of the UK science groups has been to arrive at a possible configuration which meet most of their aims at a cost which the Solar System Committee of the SERC can afford, and to retain the possiblity of later improvement in such a way that little original expenditure will be wasted.

The list of user interests is listed in Appendix I from which it may be seen that 30 priority projects are to be supported by 15 user groups in universities and government stations, covering the broad field of study summarized in Appendix II.

Many users have neither the computer access nor the staff time available to deal with preprocessed data and have urged strongly that the radar should have its own dedicated computer facility on site and a small permanent complement of Research Council staff capable of routine operation, maintenance and engineering of the radar as well as reduction of data required within programs arranged by a user committee. Some on-site accommodation for visiting users is needed to cover non-routine program development and campaign needs.

An impression of the proposed site is given in Figure 1. Several users have asked us to reconsider making the radar containerised and transportable, but it seems better to retain this concept as a second stage separate project as the SOUSY team has done.

When UK VHF television ceases in 1984, it will still be active in neighboring states. The plan to find a Welsh mountain valley fairly near to Aberystwyth University is not favored by Met. Office users who wish to make measurements clear of the effects of mountains. On the other hand it could prove difficult to persuade our licensing authorities to allow us a 2 MHz band at 50 MHz elsewhere.

The full design study, a copy of which is available for discussion by interested workshop attendees, was presented in February 1983 to the Solar Systems Committee. The committee decided to appoint a small panel under the chairmanship of Prof. T. B. Jones (Leicester) to consider it. The panel, which invited Dr. R. Ruster to act as consultant, reported in favor of the proposal and whilst recommending some reconsideration of detail, endorsed a pre-implementation phase costing about 10% of the projected total in which the major cost features could be tested experimentally.

MAJOR FEATURES OF PROPOSED UK RADAR

From Appendix III, it may be seen that the aims of the radar are very similar in range and facility to the SOUSY Radar. Indeed some workers see benefit in collaboration using both radars, and look forward to developing their plans for using the UK radar, during the period of construction, by consultation with MPI colleagues.

1) It has been decided to limit the radar initially to DBS operation, reserving the possibility of SAD operation later either by subdividing the array or by using smaller movable subarrays.

2) To minimize the initial outlay on relays be limiting operation to vertical plus two discrete angles along two orthogonal directions.

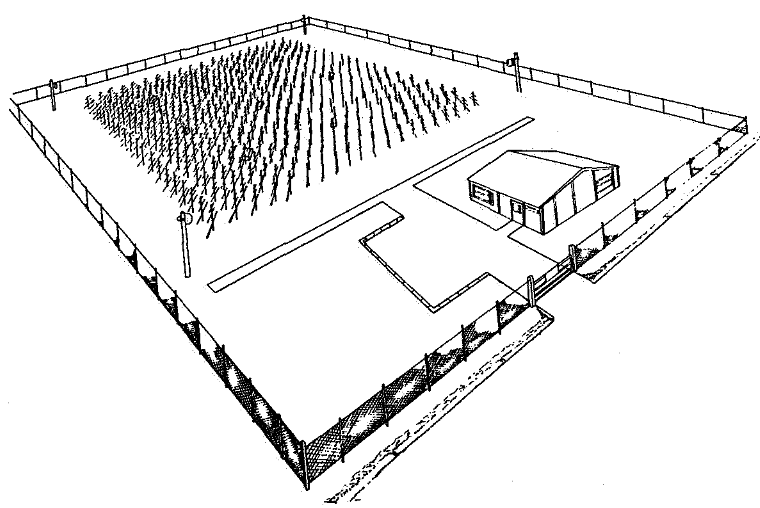

Figure 1. An artist's impression of the proposed MST radar site showing the array of 400 Yagis.

3) To modularize the assembly by energizing groups of the antenna array using about 10 medium power amplifiers producing a total of about 250 kW peak with a 5% duty ratio.

4) To opt for a 20 x 20 array off 10 x 10 co-phased subarrays of Yagi 3-element antennas.

5) To include complementary code pulse facilities.

6) To leave consideration of remote operations to a later date.

Figures 2-7 show some of the details of the proposed antenna arrangements.

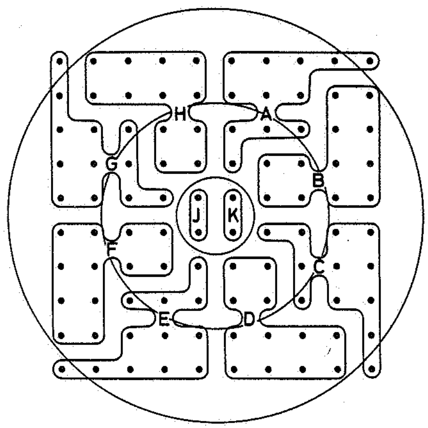

Figure 2. Plan of the 10 x 10 array of quads showing the radial power zoning necessary for sidelobe suppression. The letters A-K denote the positions of the feed points from the 10 RF amplifiers each having a mean output of 1.2 kW.

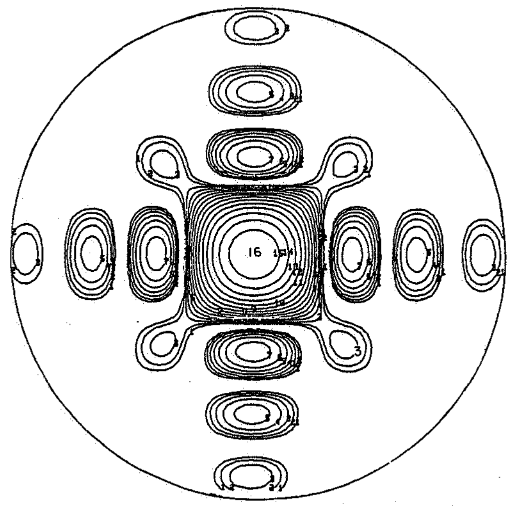

Figure 3. Zenithal projection of the spherical distribution of radiated power produced by the 400-Yagi array proposed. Contours are plotted at 2 dB intervals and the map extends to a zenith angle of 18°.

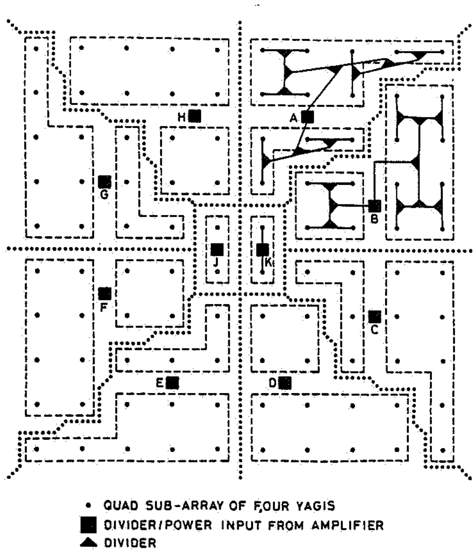

Figure 4. Plan of the 10 x 10 array of quads illustrating the power fan-out from the ten power input points A-K. The ten areas bounded by dotted lines are the sections of the array each powered by a transmitter; apart from the two small inner areas the array has an octantal structure.

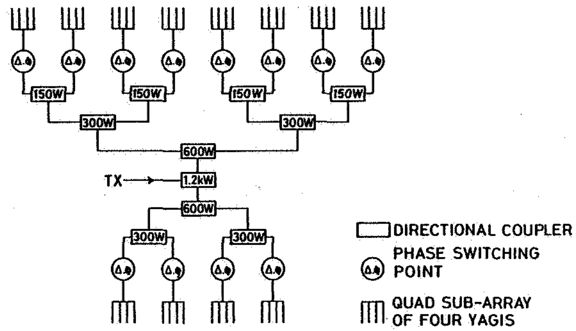

Figure 5. Power distribution network for the two outer rings of the array in one of the octants.

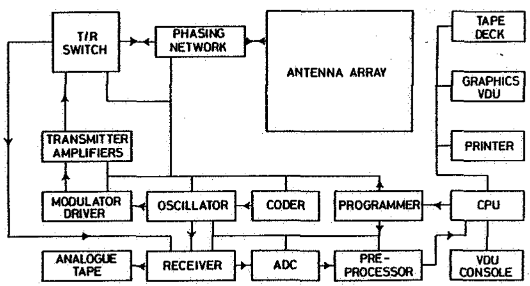

Figure 6. Block diagram of the proposed radar system.

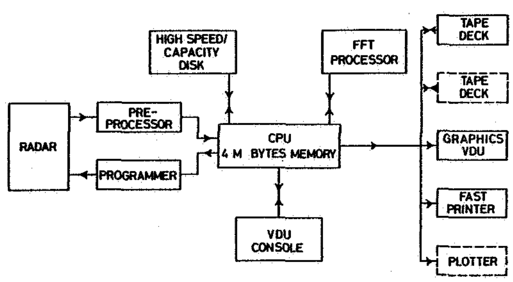

Figure 7. Configuration of the real-time data processing system.

APPENDIX I

Priority Programmes

Mesosclae eddy transport in the low stratosphere	Atmospheric Physics, Oxford	SERC
Mesoscale Frontal Structure	Reading University	NERC
Coordinated measurements of wind shears (VHF) and atmospheric densities (lidar) to identify dynamically and statically unsuitable regions, gravity waves (VHF) and turbulence (C_n^2 from VHF)	University College of Wales, Aberystwyth	SERC
Coordinated measurements of motion field, including vertical component, and tropopause height (VHF), properties of cirrus clouds (lidar) and temperature and water (radiosonde)		NERC
An investigation of the role of jet stream and frontal layer instabilities in the formation and launching of freely propagating gravity waves		SERC/ NERC
A study of the coherence of waves as they propagate through the middle atmosphere		SERC
Nonlinear interactions of gravity waves		NERC/ SERC
The evolution of the wave spectrum		NERC/
Planetary waves in the troposphere, stratosphere, and mesosphere from day-to-day variability in average wind profiles		SERC
Acoustic wave and pulsation studies	University of Leciester	SERC
Upward propagation of internal gravity waves (using MST HF Doppler)		SERC
VHF communication link performance		SERC
Investigation of air flow around jet streams with particular emphasis on investigation of the occurrence of intrusions of tropospheric air into the stratosphere	Meteorological Office	MOD

Comparison of radar-measured winds, tropopause height and static stability with those obtained by coincident sequential radiosonde ascents	Meteorological Office	MOD
Gravity-wave mode structure	RAL	SERC
Critical level motions		SERC
Horizontal extent of atmospheric structures (with MPI).		
LONG-TERM PROGRAMMES		
Upper mesospheric cellular structures and transport dynamics	QUB	UGC/ SERC
Statistical study of turbulent layers (thickness, occurrence frequency and duration) in stratosphere for studies of vertical transport by turbulence	University College of Wales, Aberystwyth	SERC/ NERC
A determination of the seasonal behavior of gravity-wave propagation in the middle atmosphere; the effect of the summer mesopause on wave reflection and dissipation		SERC
Trans-tropopause interchange	University of Edinburgh	UGC/ NERC
Lunar tidal analysis	Exeter University	SERC/ UGC
Studies of short period pulsations	University of Leicester	SERC
Synoptic studies of gravity waves and neutral wind interaction		SERC
Obtaining long period (1 year) data on the frequency of stratosphere-troposphere exchange events	Meteorological Office	MOD
Collection of statistics of stength of return as function of height, time of day/year, synoptic situation, etc., with a view to characterizing the performance required of an operational wind profiler		MOD

Climatology of turbulence in the mesosphere	RAL	SERC
Correlative studies of tropopause height and temperature		SERC
Off-vertical wave propagation (with MPI)		SERC
Dependence of upward wave coupling on temperature field (with Oxford, PMRs)		SERC

APPENDIX II

1. Middle Atmosphere Motions - Problem Areas

(i) Mean circulation - particularly above 50 km;

(ii) Planetary waves - particularly above 50 km;

(iii) Tides:

Morphology - temporal and spatial variability

Effects on mean winds and temperatures

Generation of gravity waves and turbulence;

(iv) Gravity waves:

Morphology - seasonal and geographical variability

Sources - orography, penetrative convection, wind shears (jet stream)

Propagation - temperature and winds (critical layers)

Breaking and dissipation - turbulence

(v) Turbulence:

Generation by breaking and dissipation of tides and gravity waves (intermittent, spatially and temporally)

Importance of convective and shear turbulence (average large scale flow?)

Origin of laminar and turbulent structures

Relationships between turbulence parameters (diffusion, eddy dissipation rate) to radar scatter.

2. Proposed Usage of MST System

1. Gravity-wave generation, propagation and dissipation.
2. Role of dynamics in formation of cirrus clouds.
3. Association of structures in height variation of stratospheric constituents with features of small-scale motion field.
4. Interchange of material between stratosphere and troposphere.
5. Vertical propagation of acoustic waves.
6. Propagation and scattering mechanisms for VHF waves.
7. Structure and velocities of fronts.
8. Generation of gravity waves at fronts leading to enhanced convection and rainbands.
9. Generation and characteristics of tides.
10. Vertical propagation of planetary waves.
11. Vertical structure of winds for synoptic studies of troposphere and stratosphere.
12. Statistics and characteristics of turbulent and stable layers as input to numerical models.
13. Small-scale turbulence and waves in stratosphere and mesosphere.
14. Nonlinear processes involving gravity waves.
15. Vertical momentum transport by gravity waves and influence on mesospheric circulation.

3. Exploitation of MST System

Development of operational wind sounder by Meteorological Office

Observations of troposphere and stratosphere in Antarctica by British Anarctic Survey.

APPENDIX III

Performance Specification of the Proposed System

Engineering parameters

The values of the radar engineering parameters are given below:

<u>Transmitter</u>

Frequency:	50 MHz	The exact frequency cannot be specified before further discussions with the Home Office
Peak pulse power:	240 kW	This figure represents the total power from the ten amplifiers
Duty cycle:	5%	
Mean power:	12 kW	
Pulse length:	1 to 64 μs in 1 μs steps	Pulse codes of up to 32 bits could be used
Pulse repetition frequency:	1 to 6 kHz	continuously
Bandwidth:	2 MHz	Determined by the shaping of the minimum pulse length desired

<u>Antenna</u>

Area:	5184 m^2	The array will comprise 400 3-element Yagis arranged in a 10 x 10 matrix of 2 x 2 quads
Gain:	Total array: >33 dB Each quad: >19 dB Each Yagi: 6 dB	
Half-power beam width:	3.6°	
Beam directions:	0° and approximately 5° and 10° off zenith in both the x and y directions	
First null:	5.2° off zenith	
First maximum:	7.2° off zenith	
Second null:	9.5° off zenith	
Side-lobe suppression:	Better than 17 dB (at first maximum) and better than 20 dB beyond 12°	

<u>Mean power aperture</u> 6.2×10^7 Wm^2

<u>Receiver</u>

Dynamic range: 70 dB

Noise figure:	3 dB	
IF bandwidth:	4 MHz	
Protection:	Up to 20 V peak RF input	
Outputs:	In-phase and quadrature	
Filters:	Four Bessel filters with values between 1 and 500 μs selected by user	
<u>T/R switch</u>		
Switch time:	<5 μs	This together with cable delays, will limit the minimum height range to 1 km
<u>A/D converters</u>		
Conversion time:	1 μs	
Resolution:	10 bits linear	
<u>Pre-processor</u>		
No. of coherent integrations:	1024	
Memory capacity:	2 x 1024 20-bit words	

<u>Performance parameters</u>

The values of the performance parameters of the radar are indicated below; they are based on the values of the engineering parameters.

Height-resolution	150, 300 and 600 m	These correspond to effective pulse lengths of 1, 2, and 4 μs
Maximum height achievable	Between 75 and 85 km by day	
Operating height ranges:	1-25, 1-30, 1-37.5 1-50, 1-75 and 1-150 km	These figures correspond to pulse repetition frequencies of 6, 5, 4, 3, 2, and 1 kHz
Doppler frequency bandwidth:	3, 6, or 12 Hz	These figures depend on the data sampling rate i.e., the PRF divided by the number of coherent integrations
Dwell times:	5, 10 or 20 s	

Doppler frequency resolution:	0.05, 0.1 or 0.2 Hz	These figures are the reciprocals of the dwell times
Velocity resolution:	2, 1, or 0.5 ms^{-1}	The velocity resolution is directly proportional to the Doppler frequency resolution and therefore depends on the dwell time. The figures quoted are estimates for time-resolutions of 15, 30 and 60 s, respectively.
Time resolution:	15, 30 or 60 s	