P5.7 FEASIBILITY OF HIGH ALTITUDE PLATFORMS FOR WEATHER RADAR

Robert J Watson*
Dept. of Electronic and Electrical Engineering, University of Bath, UK

1. INTRODUCTION

High Altitude Platforms (HAPs) have been conceived as a system for the provision of broadband services to the home; an alternative to satellite and terrestrial fixed wireless access. It is intended that HAPs will operate in the stratosphere at an altitude of 20-22km. A number of technologies have been proposed for the platform itself including solar powered airships and high altitude aircraft. In this paper we assess the feasibility of operating a downward looking atmospheric radar payload. The paper considers firstly how any possible benefits would be realised and secondly if such a system would be technically possible.

2. POTENTIAL ADVANTAGES OF HAP RADAR

Rainfall rate estimation is notoriously difficult in urban areas, as illustrated in fig. 1. Raingauges provide only a point measurement of rainfall rate, have limited dynamic range and are difficult to site. Conventional ground based weather radars whilst providing spatial information will almost certainly suffer from beam blockage, and clutter problems. Techniques have recently been proposed that estimate path integrated rainfall rates using dual frequency links, however a weakness is that such techniques provide no spatial information. Rainfall rate estimation in mountainous regions such as Switzerland is similarly problematic, with clutter suppression and blockage remaining key issues.

A HAP platform operating at 20km has the potential to match or better the spatial resolution of a ground based radar, whilst at the same time given the near-nadir incidence angles (dependant on the coverage required), the problems of beam blockage will be greatly reduced.

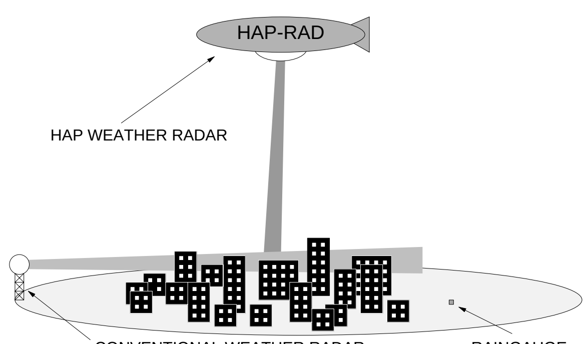

Figure 1: Comparison of rain sensing techniques

* *Corresponding author address*: Dr R J Watson, Dept. of Electronic & Electrical Eng., University of Bath, Bath, UK. BA2 7AY. R.J.Watson@bath.ac.uk, http://www.bath.ac.uk/~eesrjw

In addition to the benefits due to the measurement geometry, there are other benefits compared to conventional airborne radar and satellite platforms. Since the platform is quasi-stationary, the dwell-time can be longer if required, thereby increasing the number of independent samples, thus reducing the measurement variance.

3. HAP PLATFORMS

High altitude platforms operating in the stratosphere have been proposed that make use of either airship or aircraft technology. There are a number of constraints imposed by the platform technology, not least is the payload mass and power consumption. The planned characteristics of platforms being considered are shown in Table 1 (SkyStation, Heliplat, Angel Technologies).

Table 1: Comparison of HAP capabilities

	High Altitude Platform type		
	Airship	Solar plane	Jet plane
Length (m)	160	60	24-28
Total mass (kg)	30,000	1,000	2,500
Payload mass (kg)	1,000	100	1,000
Payload power(kW)	20	1	40
Energy source	Solar	Solar	Kerosene
Flight endurance	5+ years	Months	8 hours

It is intended that the airships will be kept on station to better than 1km, with exact positioning using GPS, while the aircraft will fly in a circular orbit 5-8nmi in diameter. Figure 2 shows an artist's impression of the airship HAP being considered by SkyStation International for broadband services.

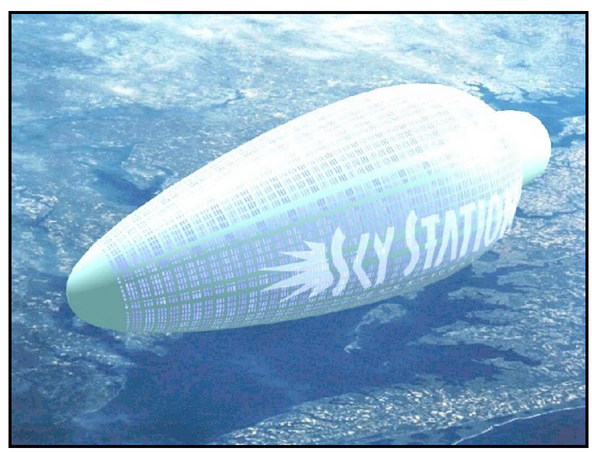

Figure 2: Airship based HAP (SkyStation International)

4. RADAR SPECIFICATION

There are a vast number of parameters that need to be specified. Some of these are considerably constrained by the platform. Some are of course interrelated; in particular the transmitter power, antenna size, beam-width and resolution. There also a number of practical and technology related issues that need to be addressed, particular relating to the antenna and its associated scanning system. In order to be of value, HAP radars must offer considerable improvement over conventional techniques. Table 2 shows the antenna size and associated beam-width for nadir footprint diameters (NFD) of 250m and 500m for selected frequencies between 9.38GHz to 35GHz.

Table 2: Antenna size as a function of frequency

Wavelength (cm)		3.20	2.17	1.25	0.86
Frequency (GHz)		9.34	13.8	24.0	35.0
Antenna Diameter	NFD= 250m	3.25	2.20	1.27	0.87
	NFD= 500m	1.63	1.10	0.63	0.43
Beam-width	NFD= 250m	0.72 degrees			
	NFD= 500m	1.43 degrees			

Another key parameter of the radar specification is coverage area. For a given altitude the coverage area will define the scanning angles required of the antenna system. Figure 2 shows the antenna beam steering angle as a function of coverage area (km^2), and HAP altitude, h. To put this in context, Greater London in the UK is approximately 1700 km^2.

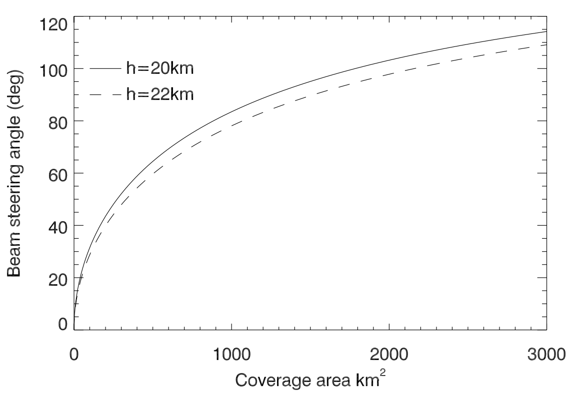

Figure 2: Coverage area

A key consideration is the sensitivity of the radar for a given peak transmit power and pulse duration. Figure 3 shows the received power at a range of 20km for a single $1\mu s$ pulse with a peak-power of 1kW, using the antenna parameters defined in Table 2.

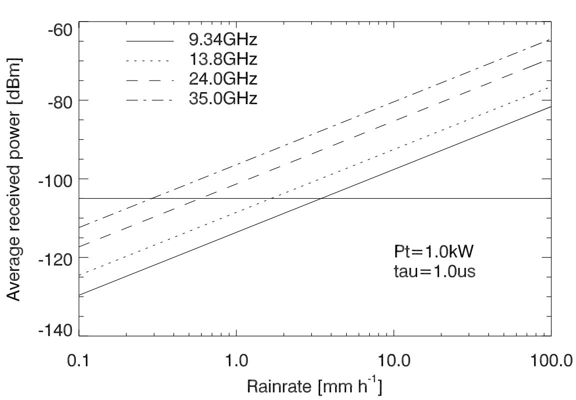

Figure 3:Sensitity as a function of rainfall rate and frequency

It can be seen that for a receiver sensitivity of −105 dBm (a readily achievable value) and 0 dB SNR a sensitivity of 0.5mm h^{-1} (at the rain top) can be obtained at 24GHz. Attenuation of course has a large effect on the sensitivity, particularly at the shorter wavelengths.

5. ANTENNA SCANNING SYSTEM

This problem presents a number of possible solutions. However due to economic and physical constraints a number of options can be eliminated. An electronically steered phased array antenna solution, although attractive would be costly. A mechanically steered reflector antenna would almost certainly be too bulky. One possible solution would be to mechanically steer a planar fixed phased array. This could be done as illustrated in fig. 4 below. The antenna is rotated back and forth to scan the swath, and then rotated about its axis of symmetry to complete the scan.

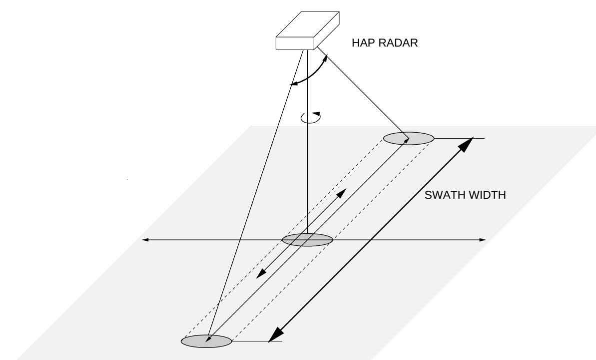

Figure 4: Proposed scanning strategy

6. RETRIEVAL ALGORITHMS AND CALIBRATION

Since it is inevitable that the radar will suffer from attenuation effects, estimation of surface rainfall rate will be non-trivial. There are however a number of mature algorithms as a consequence of TRMM and airborne radar studies, e.g. mirror echo techniques.

Calibration of weather radar systems is a key issue. Receiver calibration can be accomplished by directly injecting a signal into the receiver. It would also be possible to place low power CW transmitters on tall buildings within the coverage zone. These would effectively act as a microwave link, which could be used to derive path integrated attenuation values to improve the rainfall retrievals.

7. CONCLUSIONS

This paper presents very brief first look at the possibility of using HAP technology to carry a atmospheric radar payload. In principle such a radar is readily realizable.

REFERENCES

SkyStation International, *http://www.skystation.com*
Angel Technologies, *http://www.angeltechnologies.com*
Heliplat, *http://www1.tlc.polito.it/heliplat*