פלטפורמות בגובה רב SQSP לממסרי תקשורת, מכ"ם, חישה מרחוק והעברת אנרגיה באלחוט מן הקרקע למטרות התראה והרתעה

פרופסור יעקב גוון HIT   Fellow IEEE

World Map of Stratospheric / HAPS Activities

מערכות תקשורת והתראה באמצעות לוויינים ופלטפורמות בסטרטוספרהSQSP ו HAP

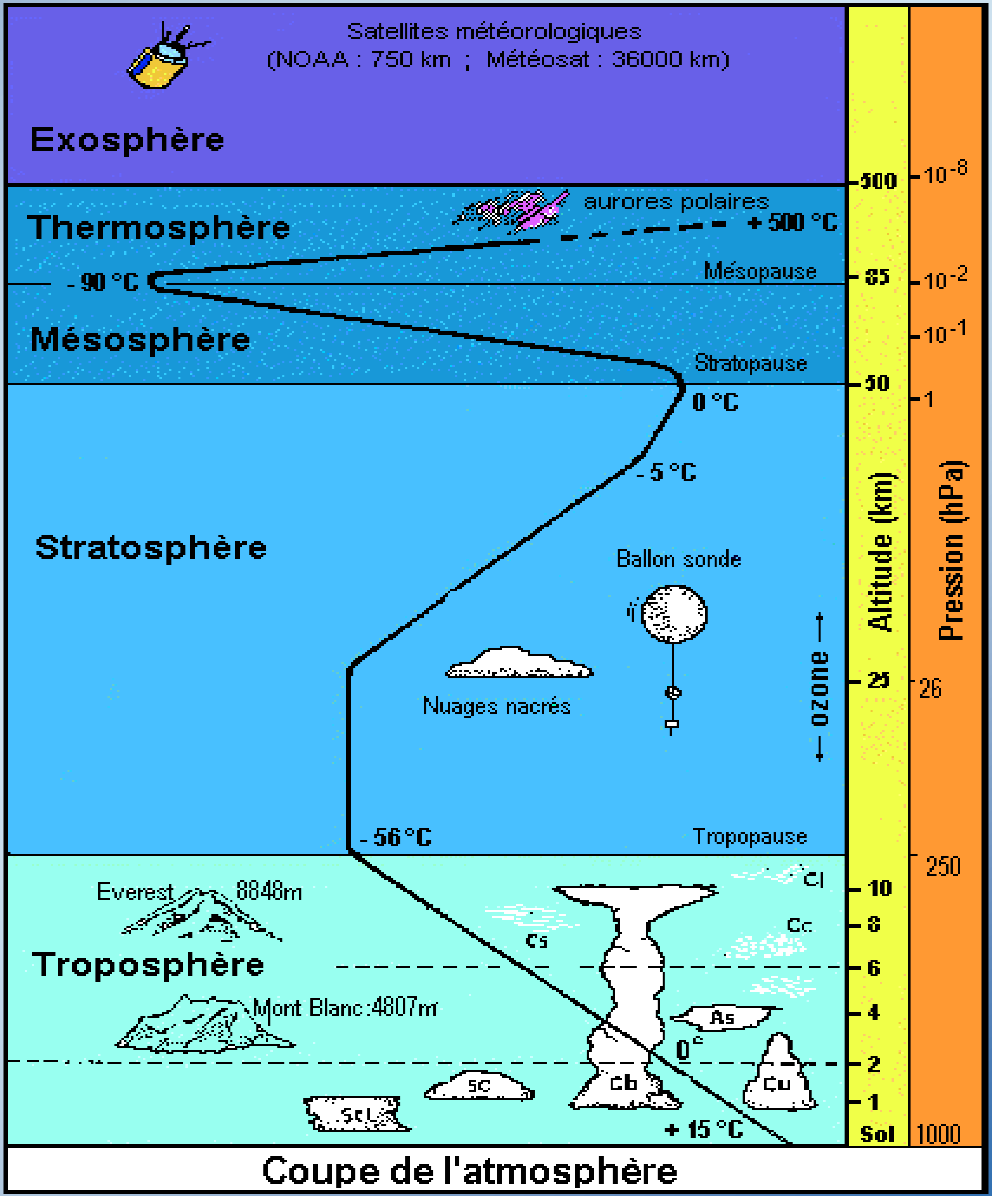
- לוויינים במסלול גאוסטציונרי בגובה 36 אלף ק"מ במסלול מעל ל קו המשווה. כ לווייני עמוס.
- לווייני ניווט במסלול בגובה כ20000ק"מ כ GPS
- לוויינים במסלול בינוני MEO בגובה בין4,000 ל-8,000 ק"מ כלווייני O3B
- לוויינים במסלול נמוך LEO בגובה בין 300 ל-2,000 ק"מ כ IRIDIUM. וVLEO בין 150 ל-300 ק"מ
- פלטפורמות בסטרטוספרה SQSP בגובה בין 17 ל-24 ק"מ. ZEPHIR ו AALTO ככלי טייס כבד מאוויר ו AEROSTAT ו בלונים קלים מן האוויר.
- פלטפורמות באטמוספרה HAPs בגובה מתחת ל- ק"מ17 Advanced Hawkeye Airborne Platforms, Heron,

Why Stratospheric (SQSP)?

- Atmospheric Structure

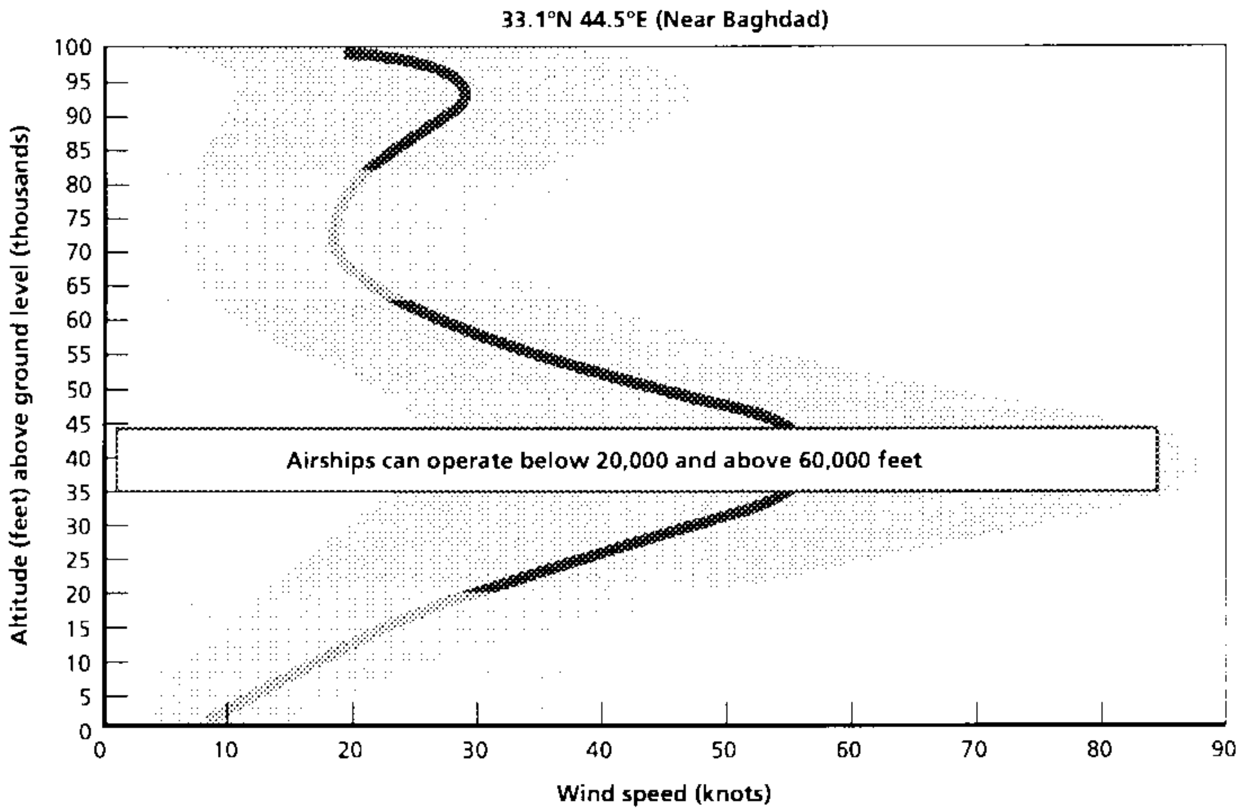
The temperature Effect

Minimum temperature. is equivalent to minimum cupper losses, thermal noise, and power dissipations problems and maximum receiver sensitivity.



The Wind Factor

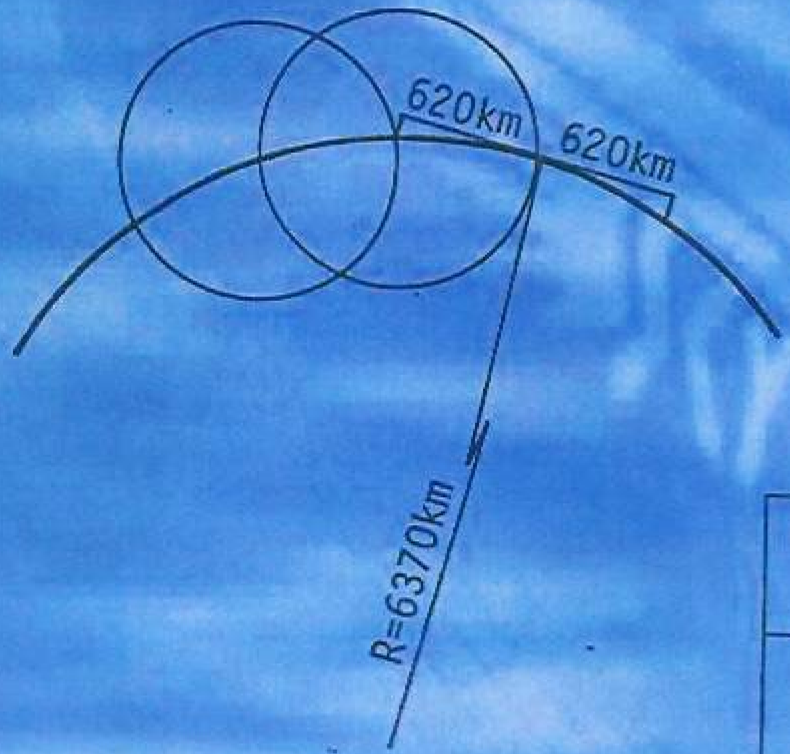
Figure S.1
Annual Winds Aloft Near Baghdad



NOTE: Summary product created from raw weather data collections provided by AFCCC/DOPT (Asheville, North Carolina) dated from 1958 through 1990.

SOURCE: Stephen Huett, Director, Advanced Development Program Office for Airship Concepts, Naval Air Systems Command, "Current State-of-the-Art for LTA Systems," briefing, January 2005. Used with permission.

Line Of Site (LOS) Distance as Function of the Altitude



$X = 113\sqrt{h}$ (km)

h	x km	2x km	x_{RH} km
21	517	1034	597
30	618	1236	714
40	714	1428	824
50	798	1600	922

*** Operation Radius and Diameter as function of HAPS height**

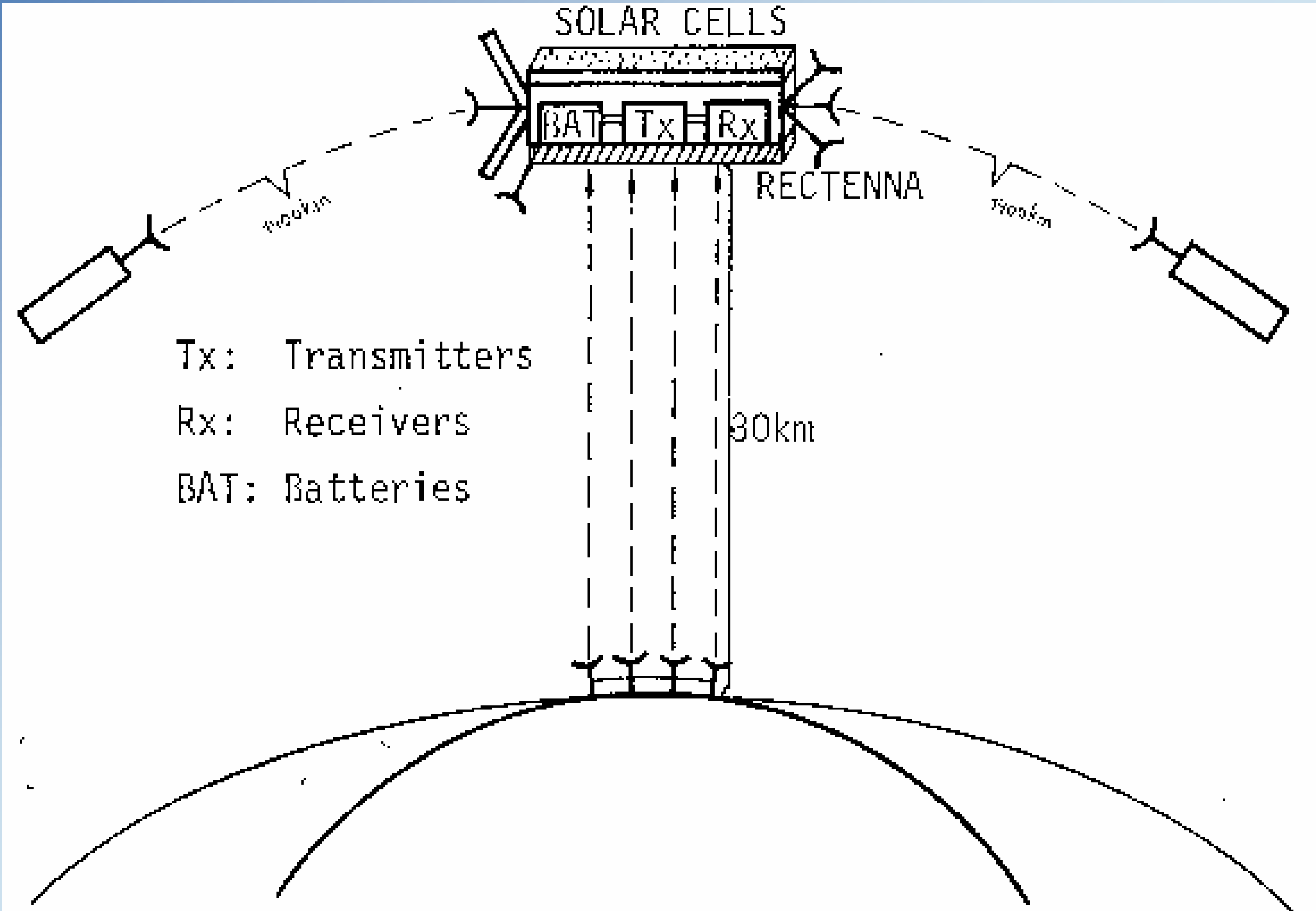
SQSP Advantages on Satellites and Towers

- Low Cost (Sat. and launching),
  Low maintenance Cost.
- Low Free Space Loss
- Short Time Delay
- Low transmitters power Consumption
- High Reception Sensitivity
- Large coverage zone and LOS relative to ground communication. Less then for satellites
- One HAP can replace more than 400 terrestrial towers

SQSP Disadvantages on Satellites and Towers

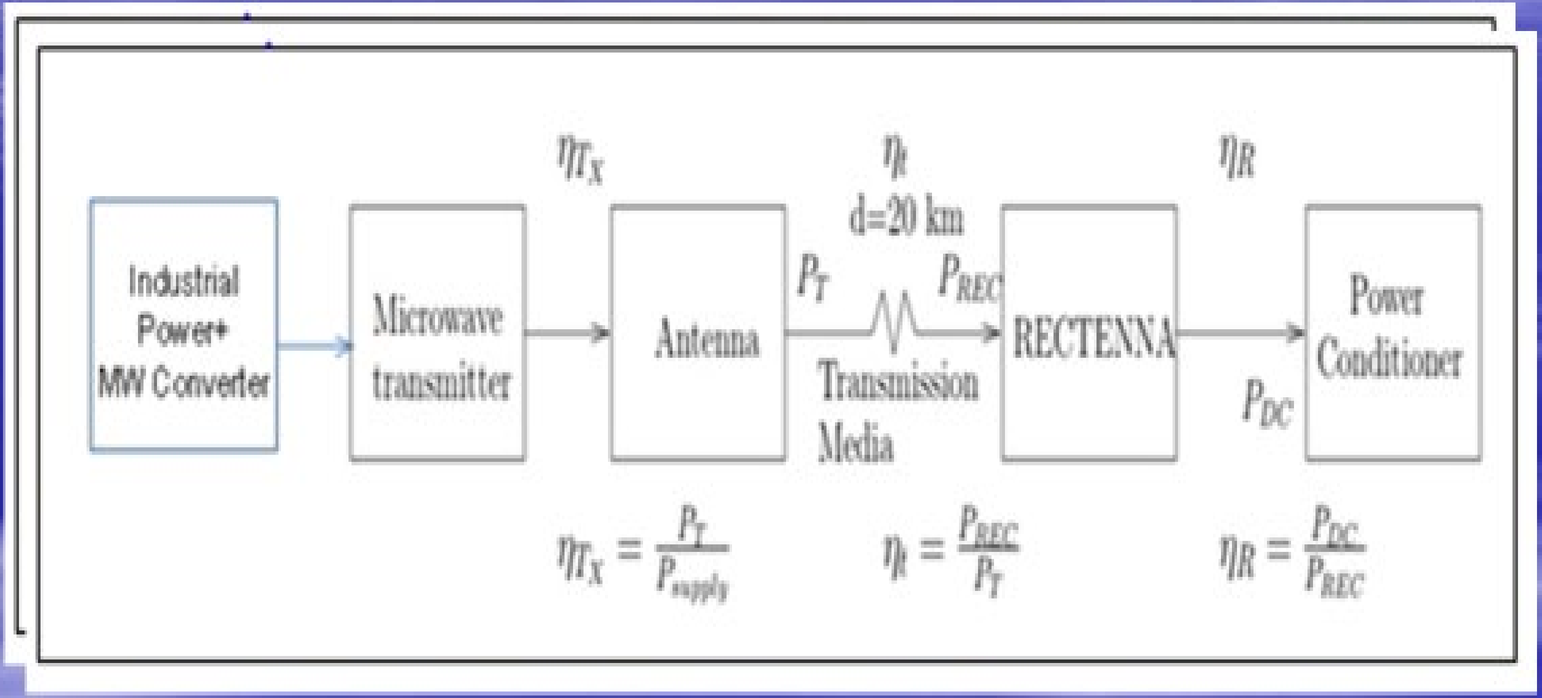
- Less Energy from Solar Cells than from Satellites
- More vulnerable to attacks than satellites.
- More vulnerable to Jamming than satellites
- Penetrate Airspace
- Not Yet Mature Technology

SQ-SP שמקבלים אנרגיה MW מן הקרקע



The Quasi Stationnary Platform Schema

Block Diagram of a Typical Long Distance MW WPT System



מערכות גלובליות להתראה מאיומים

- כיום למעצמות העל מערכות התראה גלובליות מטילים כטב"מים ואיומים אחרים,
- ישראל נעזרת במערכת SBIRS של ארה"ב שמאוד יקרה ומורכבת מהרבה לוויינים במסלולים שונים
- המערכת לא פעלה באסון של 7 לאוקטובר אבל מאוד עזרה לנו בהתקפות הטילים מאירן
- ארה"ב מפתחת על בסיס Ai וML מערכת OPIR Overhead Persistent Infrared גלובליות
- הוספת מערכות אזוריותSQSP מוזנות באמצעות אלחוט באנרגיה מן הקרקע או מלוויינים עשויה לתרום לשפור מערכותOPIR, שמירת הגבולות ומטרות אחרות

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2. J. Gavan, S. Tapuchi and D. Grace, "Concepts and Main Applications of High-Altitude-Platforms Radio Relays," The Radio Science Bulletin, 330, September 2009, pp. (20-31).
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7. Deutsche Telekom, 5G HAPS Demo in the Kingdom of Saudi Arabia Demo report summary, Feb 2022
8. J. Gavan, M. Haridim, Evolution of Long Distances Directed Energy Systems for Commercial and Military Applications, IEEE COMCAS, June 2024

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9. Theresa Hitchens, The Army is seeking industry input to help it determine how best to deploy intelligence, surveillance, and reconnaissance payloads on very-altitude drones. Breaking Defense, Oct.12.2022
10. A. Decker, Hamas attack shows space-based sensing can't see everything, C4ISRnet, Oct, 12 .23.
11. T. Hitchens, Army about to formalize 'micro-high altitude balloons' as a new requirement for surveillance ops, Breaking Defense, October 16.24

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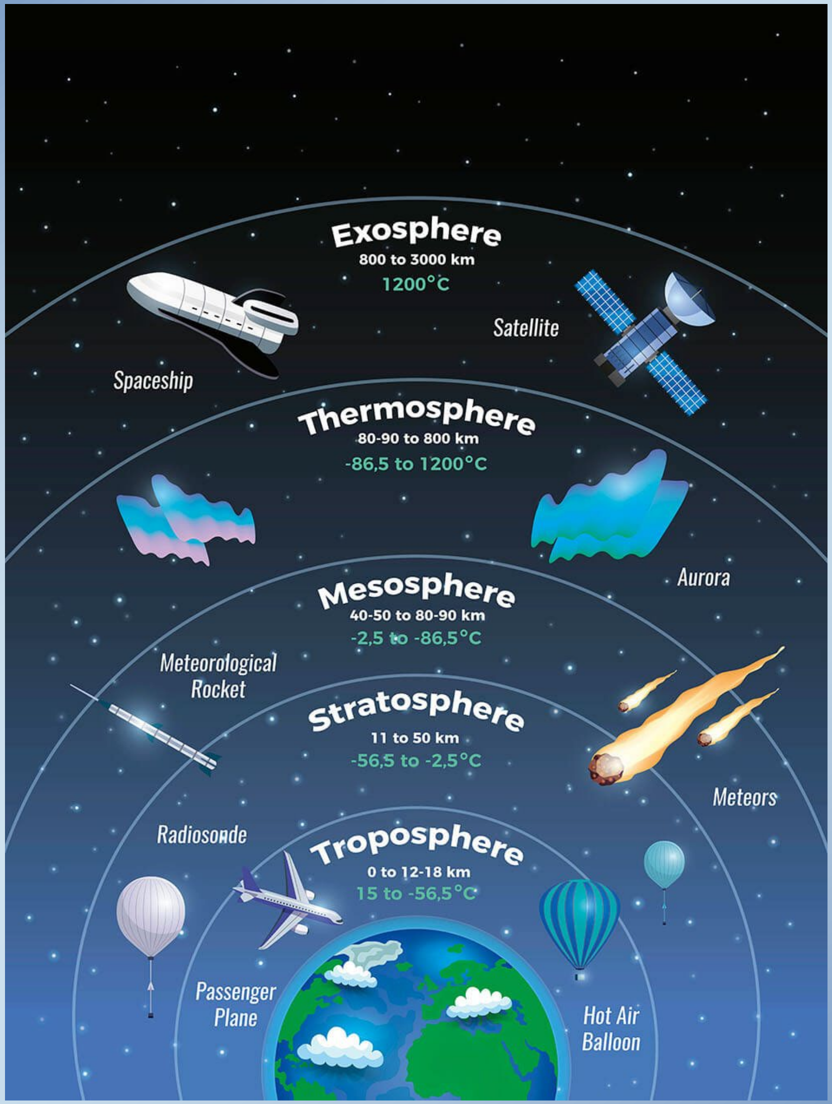
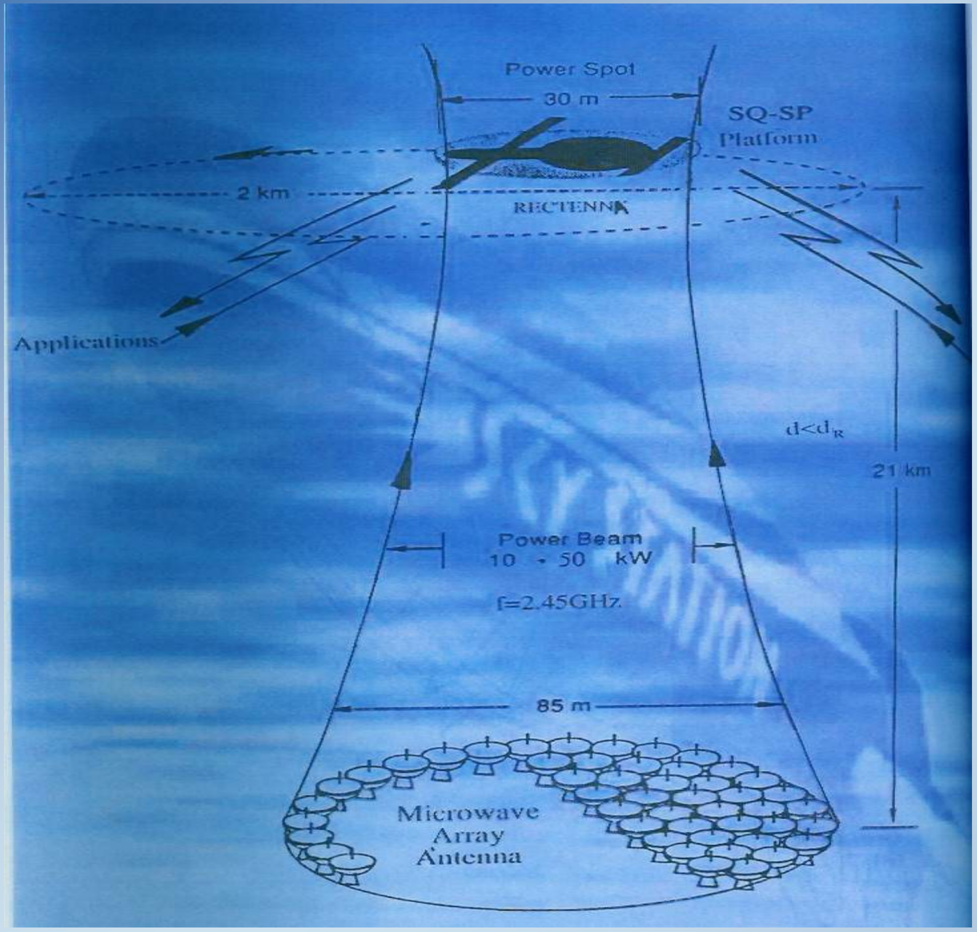
pp. (38-43)

Thank you


Exosphere
800 to 3000 km
1200°C
Spaceship
Satellite
Thermosphere
80-90 to 800 km
-86,5 to 1200°C
Aurora
Mesosphere
40-50 to 80-90 km
-2,5 to -86,5°C
Meteorological
Rocket
Stratosphere
11 to 50 km
-56,5 to -2,5°C
Meteors
Radiosonde
Troposphere
0 to 12-18 km
15 to -56,5°C
Passenger
Plane
Hot Air
Balloon

Suitable Frequency for SQSP

- 5.8 GHz ISM band. Require big surface of ground and stratospheric antennas
- 24.25 GHz ISM band. Moderate Atmospheric Losses
- 35 GHz Atmospheric Window. Low Atmospheric Losses
- 94 GHz Atmospheric Window. Higher Atmospheric Losses


Power Spot
30 m
SQ-SP
Platform
2 km
RECTENNA
Applications
d<d_R
21 km
Power Beam
10 - 50 kW
f=2.45GHz
85 m
Microwave
Array
Antenna

EMROD Worldwide Energy Matrix (WEM) to move Energy from regions of supply to consumption points, A future project: Beam Renewable Energy from Dubai to Japan

Comparison between Gaussian and Rayleigh Tappers

Figure 2a. The three-dimensional field-intensity distributions on the rectenna for the Gaussian beam.

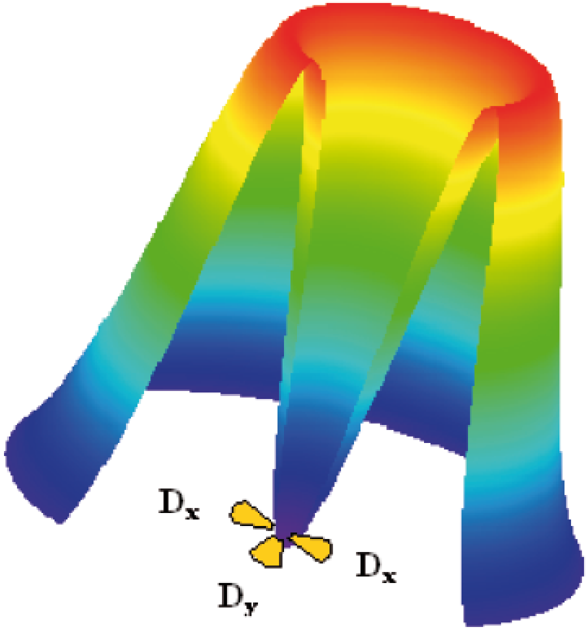
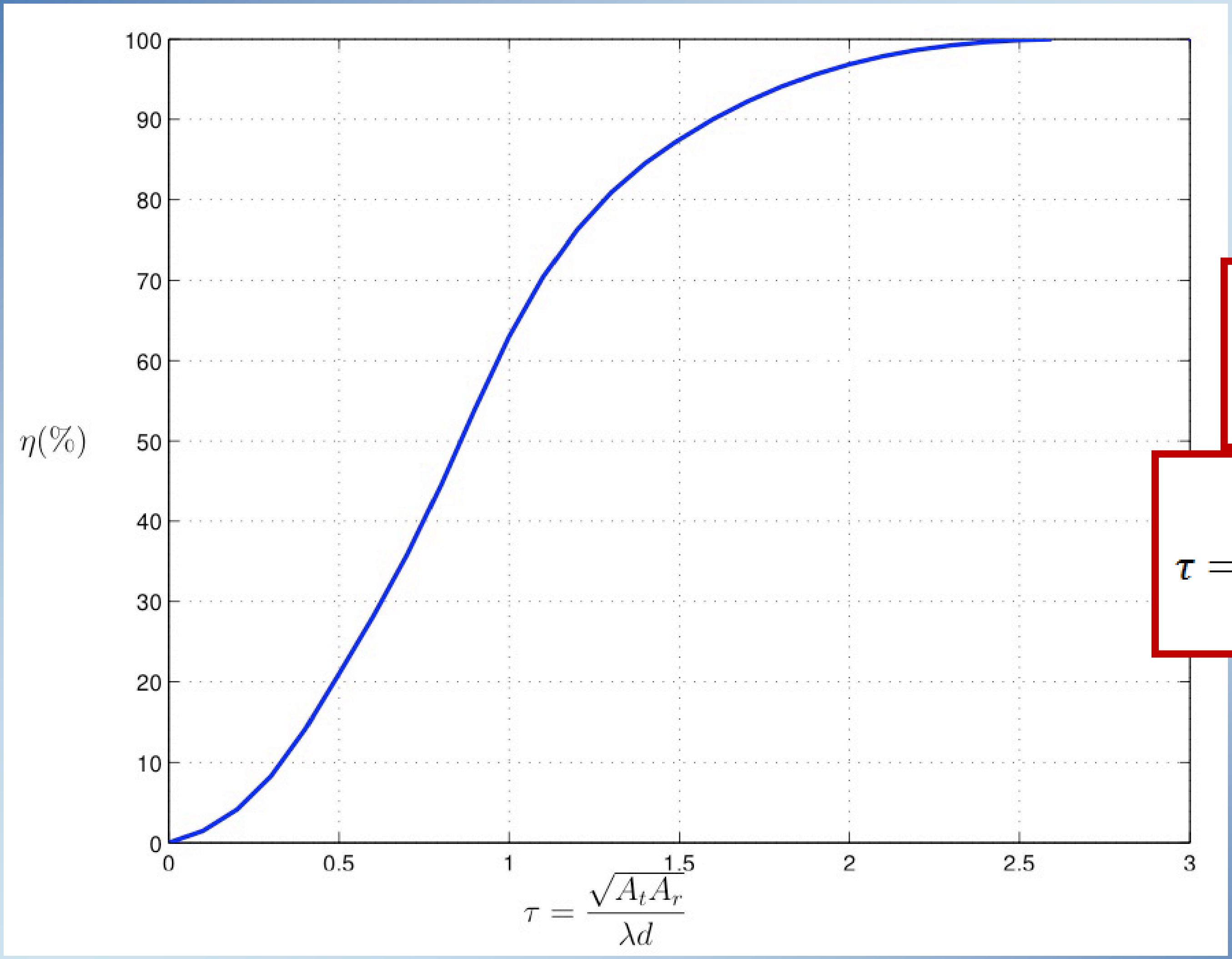


Figure 2b. The three-dimensional field-intensity distributions on the rectenna for the Rayleigh beam: D_x *and* D_y *are the quadrupole sensors.*

The Radio Science Bulletin 338; 2011 p 27.

Empirical Power Transmission Efficiency as function of tau (Goubau and W. C. Brown)



$$\eta_{t,r} = 1 - e^{-\tau^2}$$

$$\tau = \frac{10f(\mathrm{GHz})\sqrt{A_t A_r}}{3d}$$

$$\tau = \frac{2.5f(GHz)D_{T(m)}D_{R(m)}}{d(m)}$$

Numerical values of the required aperture antennas, MW beam and HAP RECTENNAS areas as function of power transmission efficiency, aperture, and frequency.

MW WPT Areas		Terrestrial d=10,000m		HAPS d=20,000m		SPS d=36000000m	
Frequency band		η_T= 60%	η_T= 95%	η_T= 60%	η_T= 95%	η_T= 60%	η_T= 95%
2.45 GHz	$A_r = A_t$ (m^2)	1224	2203	2448	4406	4.4×10^6	7.9×10^6
	$D_r = D_t$ (m)	44.1	59.2	62.4	83.7	2650	3550
5.8 GHz	$A_r = A_t$ (m^2)	517	931	1034	1862	1.9×10^6	3.4×10^6
	$D_r = D_t$ (m)	28.7	38.5	40.6	55.1	1750	2350
35 GHz	$A_r = A_t$ (m^2)	86	155	172	310	0.31×10^6	0.56×10^6
	$D_r = D_t$ (m)	11.7	15.3	16.5	22.2	705	950
94 GHz	$A_r = A_t$ (m^2)	32	58	64	116	0.11×10^6	0.2×10^6
	$D_r = D_t$ (m)	7.2	9.7	10.1	13.6	470	570

Table: The HAPS MW WPT antenna aperture: D_T, A_T and S_T for 200kW transmitted power as function of f in case of maximum power transmission efficiency (fig.6).

f (GHz)	2. 45	5. 8	24. 5	35	94
D_T (m)	70	45. 5	22. 1	18. 5	11. 3
A_T (m^2)	3850	1625	385	270	100
S_T (W/ m^2)	52	123	520	740	2000

Dt (m)=(dr(m)×0.6/f(GHz))$^{0.5}$
Dt (with HAPs dr=20000m and F=5.8GHz.
Therefore Dt=45m

Diameters as function of frequency and elevation

Ratio 1:1	Dr=Dt			
	f1= 2.45GHz	f2= 5.8GHz	f3= 35GHz	f4= 94GHz
1000 meter	12.17	7.91	3.22	1.96
20000 meter	54.42	35.37	14.40	8.79
Ratio 2:1	2Dr=Dt			
Dt 1000 meter	17.21	11.19	4.55	2.78
Dt 20000 meter	76.97	50.03	20.36	12.43
Dr 1000 meter	8.61	5.59	2.28	1.39
Dr 20000 meter	38.49	25.01	10.18	6.21

Atmospheric Losses (dB) as function of rain intensity and percentage of time Using MATLAB 2016a and Israel average climate data rain pl function (2)

Atmospheric Losses (dB) for a HAP at an altitude of 20000m and a distance of 3000m through rain if the angle of transmission is 87.13 degree:

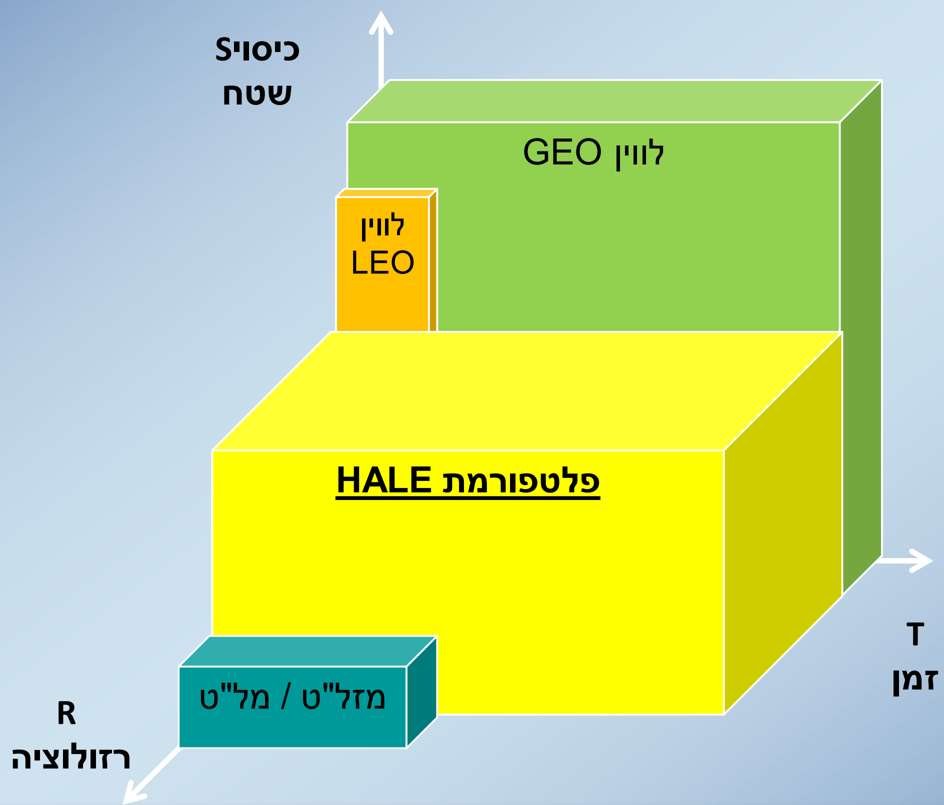
Percentage of time (%)	F – Region mm/h	2.45 GHz [dB]	5.8 GHz [dB]	35 GHz [dB]	94 GHz [dB]
1.0	1.7	0.007	0.003	1.46	5.23
0.3	4.5	0.002	0.02	3.46	10.16
0.1	8	0.004	0.04	5.75	15.00
0.03	15	0.007	0.1	9.97	22.87
0.01	28	0.013	0.27	17.04	34.37
0.003	54	0.024	0.72	28.99	51.11
0.001	78	0.033	1.21	37.59	61.47

Global Mobile (SAT) system

- Geostationary satellite (SAT) systems (Hughes)
- Small Low Earth Orbit (LEO) Sat. Systems (ORBCOMM)
- Big LEO Sat. Systems (Iridium)
- G.P.S – Global Positioning System
- Quasi-Stationary Stratospheric Platforms (HAP)

פלטפורמת HALE כמשלים ללווין ולמל"ט

T*S*R פרמטר מבצעי מכפלה :



פלטפורמת HALE משלימה את האמצעים הקיימים היום (לווין, מל"ט) מאפשרת:
רציפות בזמן, כיסוי רחב, רזולוציה גבוהה / ניחות נמוך, השהיות נמוכות ובעלויות נמוכות

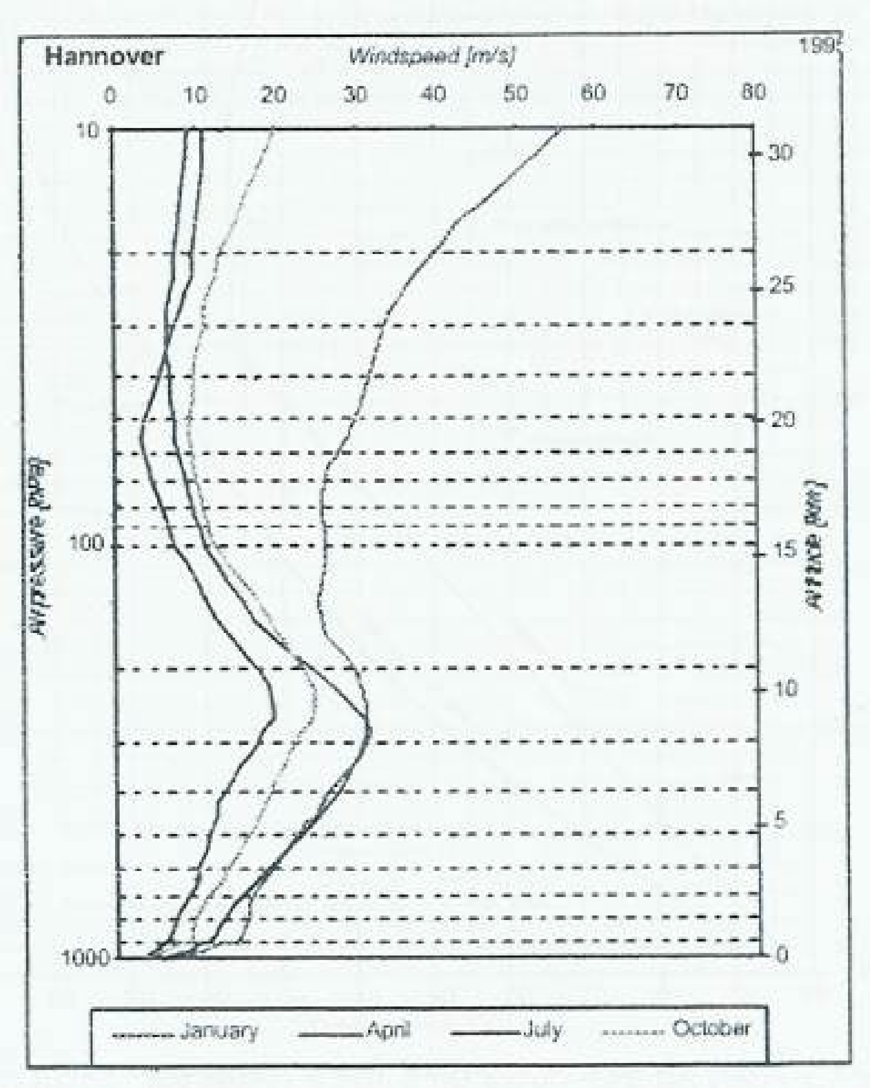
HAPS Commercial Applications

- Radio Communication, Cellular 5 and 6G backup, Improved WIMAX
- Audio and TV Broadcast (HDTV included),
- Local Communication services: Broadband internet, High rate data transfer
- Remote sensing and Imaging
- Wild fire and air pollution detection
- Weather Forecasting.
- Air and Terrestrial traffic Monitoring
- Differential GPS (DGPS)
- Scientific Applications.

HAPS Home Security and Military Applications

- Communication – Large coverage & High throughput & Low delay
  - Regional & Maritime and submarine Communication
  - Tactical Backbone
  - Emergency Communication
  - Tele operated platform
- Persistent Surveillance - Real Time & High Resolution & Large coverage
  - Border Surveillance+ Monitoring Enemy Activities !!
  - Missile Warning
  - Surveillance of Pollution, Chemical and Biological Threats
- Precision Location & Navigation

The Wind Velocity over Hanover



Detailed block diagram of a typical MW WPT system feeding a SQSP