Progress in Microwave Engineering

Microwave Power Transmission in Solar Power Satellites

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Outline

SPS:Solar Power Satellites

Definition

A Solar Power Satellite is a satellite which can be used to harvest solar energy in space and to transmit it to the ground.

Main features

- Located in a *geosynchronous orbit*. (Height:3.6×10^5 km; Linear Velocity:3.07 km/s)
- Transmitting energy using microwave. (Frequency: 5.8 GHz)

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A complete SPS system

A complete SPS system consists of a flight segment "*solar power satellite*" and a ground segment "*rectenna*".[1]

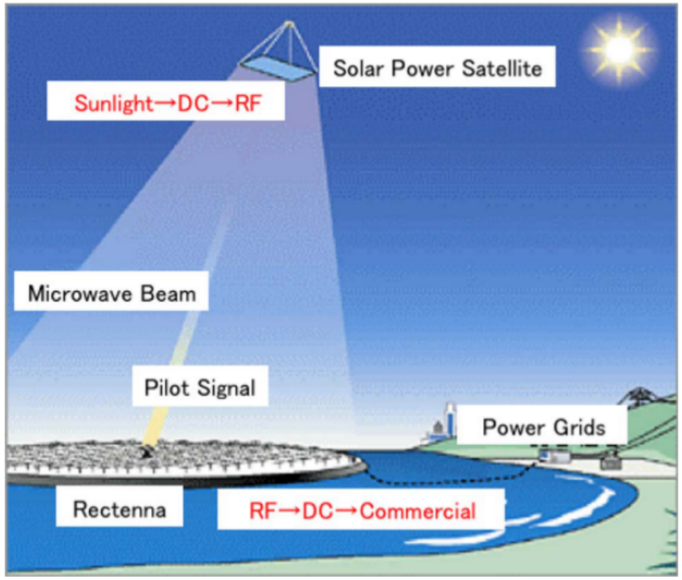

Figure : Configuration of the SPS system.[1]

Main advantages
compared to traditional terrestrial method

- Environment friendly.
- Unaffected by weather conditions.
- Much larger average solar power available per unit area.
- Much longer time in view of the sun.

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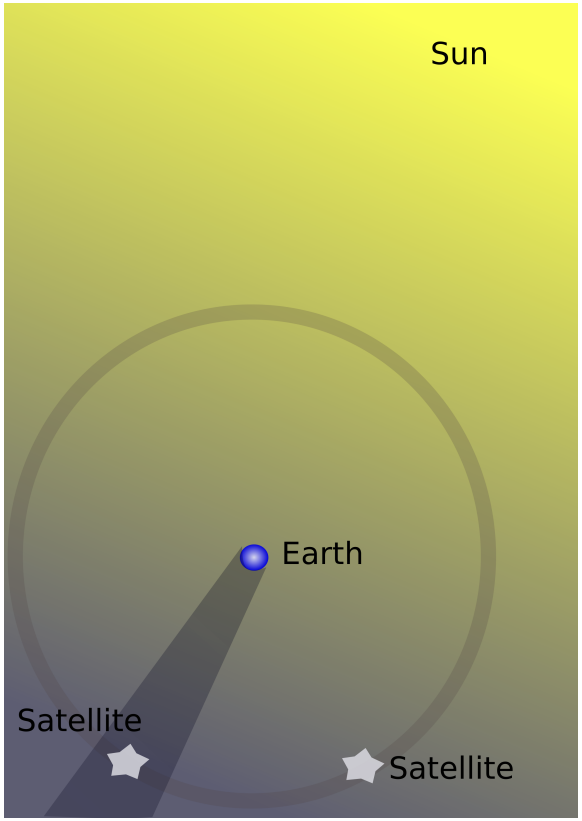
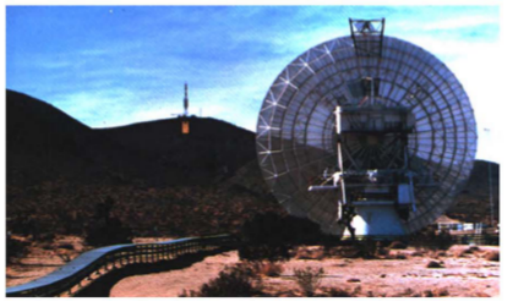


Figure : Nearly 24-hour operative.

History

- (a) Pioneering work by Nikola Tesla (early 20th century).
- (b) NASA JPL demonstration (1975)
- (c) Microwave transmission experiment in space (1983,1993)

(a)



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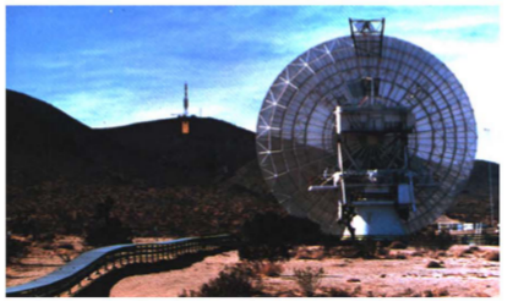

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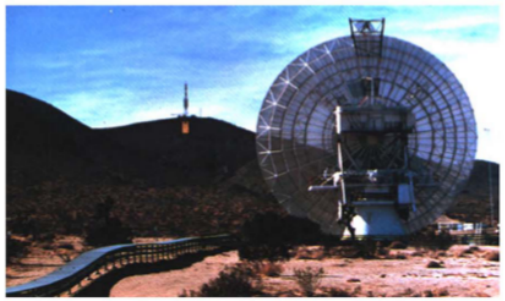

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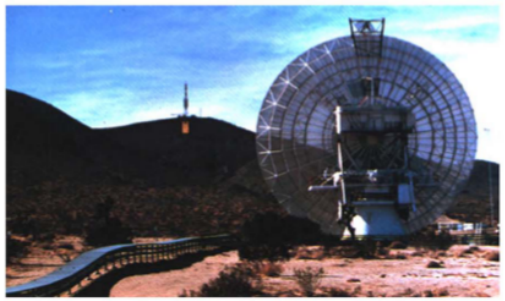

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Overview of a SPS system

An SPS system includes a solar cell array, magnetrons, circularly polarized(CP) phased arrays, and a CP rectenna array.[2]

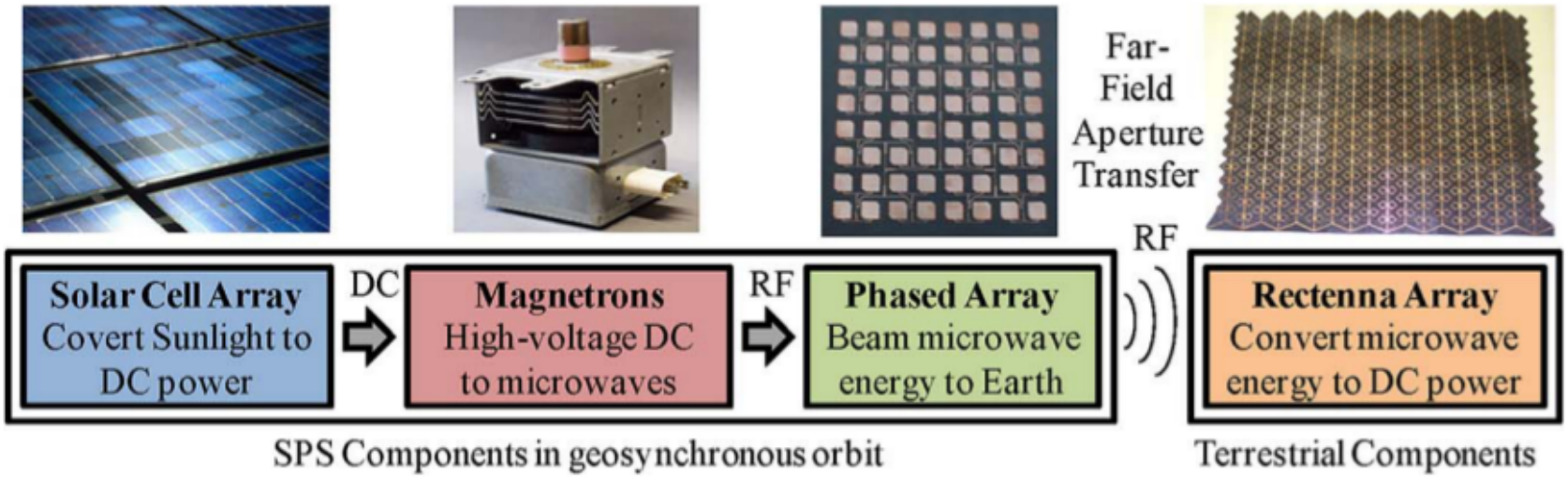

Figure : SPS system diagram.[2]

Solar cell

Technically, this is not what we are concerned. But it do become the bottleneck of the SPS system.

The efficiency of solar sunlight to dc is listed below

Practical tech

Around only 30%.

Adjustable Spectrum Lattice Matched

Up to 44% (*Solar Junction* in Oct, 2012).

Quantum Dot Tech

Theoretical maximum value is 75%, but cannot be achieved in a short term.

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For the transmitting antenna

Requirement

With a height of 3.6×10^7 m, we need a extremly narrow beamwidth to

- reduce sidelobes and spillover losses,
- minimize the terrestrial rectenna's size.

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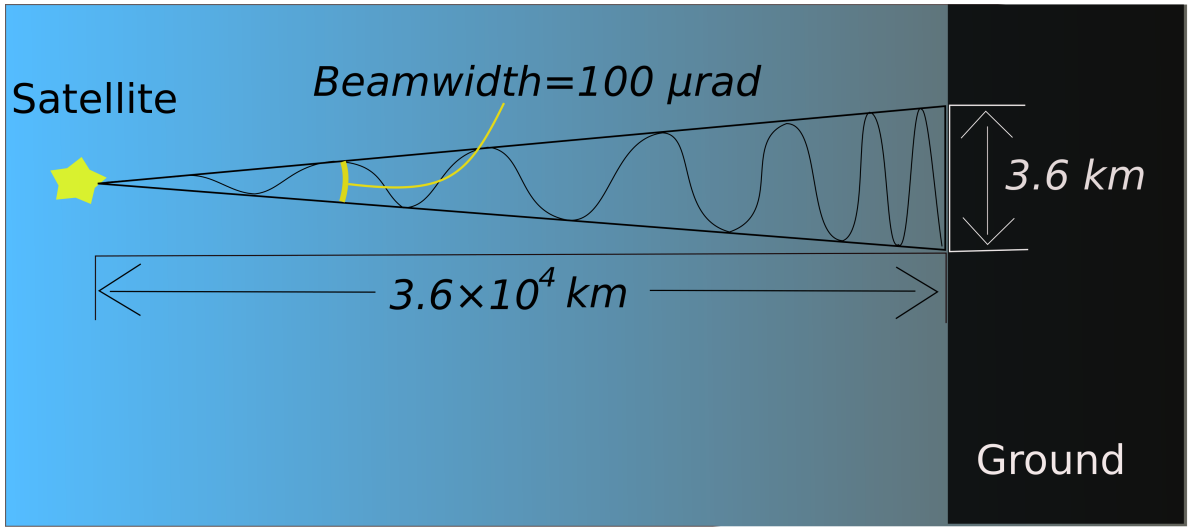

Solution: Phased Array

An Example

An array composed of 9×9 subarrays, with each subarray contains 8×8 antenna elements.

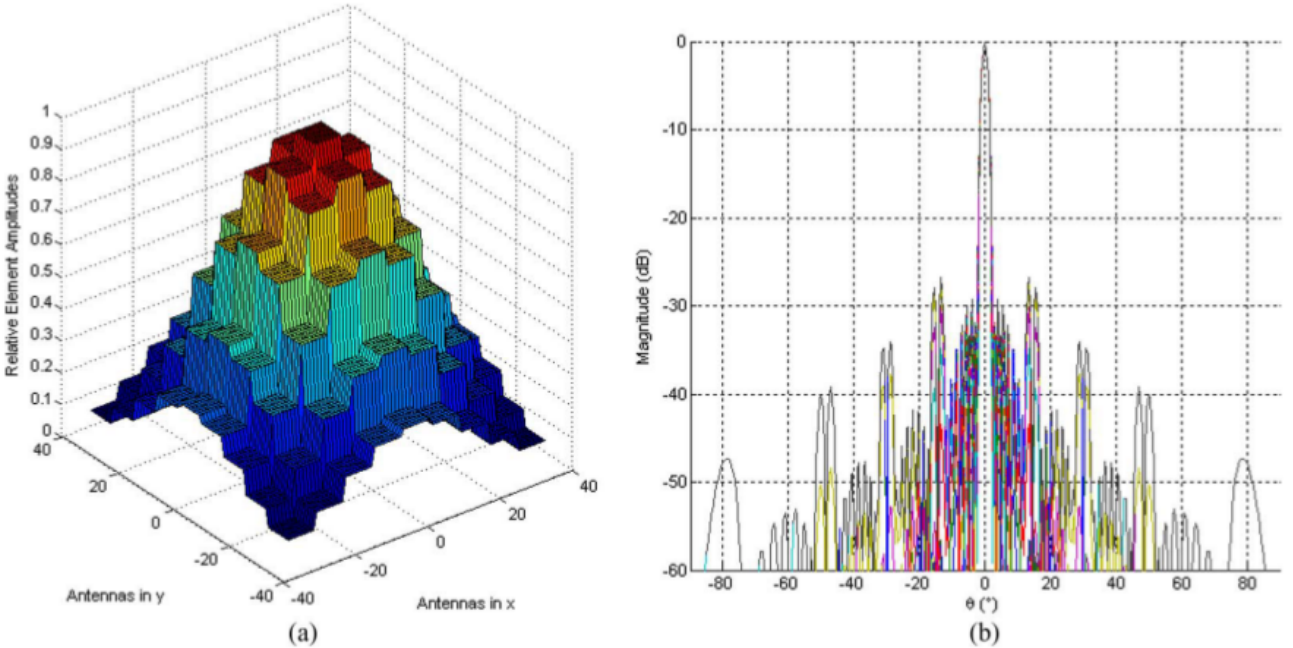

Figure : (a)amplitude taper; (b)resultant array patterns.[2]

What's Retrodirective Antenna and Why?

Definition

A retrodirective antenna is an antenna that transmits signal back in the same direction it came from.

Also due to the height of the satellite, even the slightest error of the transmitting phased array would results in a huge deviation on the ground.

A feedback loop guided by a pilot beam.[1]

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Figure : A feedback loop guided by a pilot beam.[1]

Recent Advances

Japan scientists has developed a system with accuracy of 0.4 degrees RMS in 2011.[3]

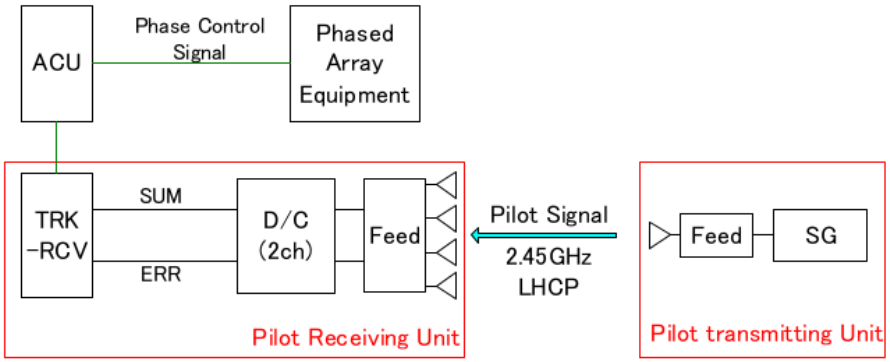


Figure : Software retro-directive system.[3]

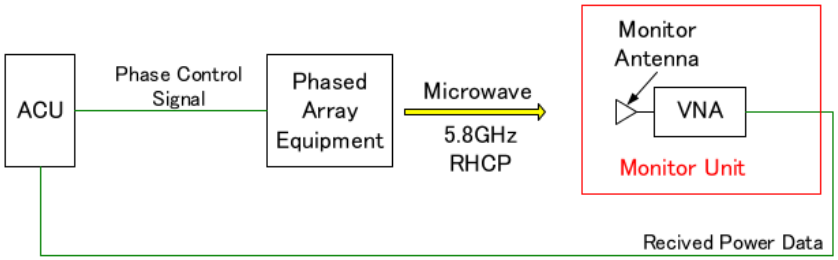


Figure : Step-tracking system.[3]

Functionality

Definition

The rectenna is used to capture and convert RF energy to dc power.

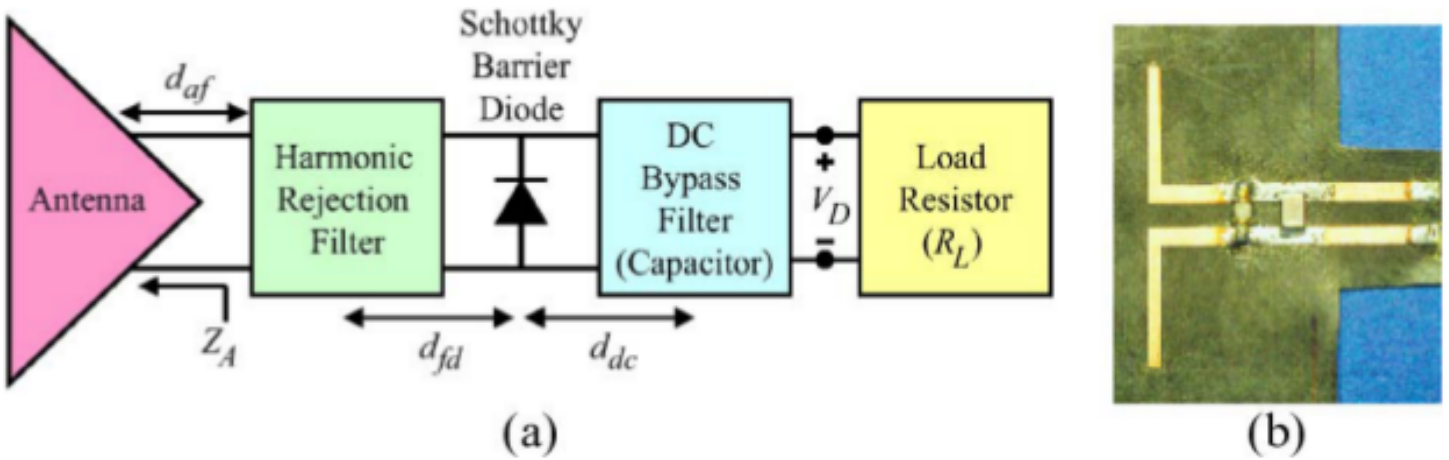
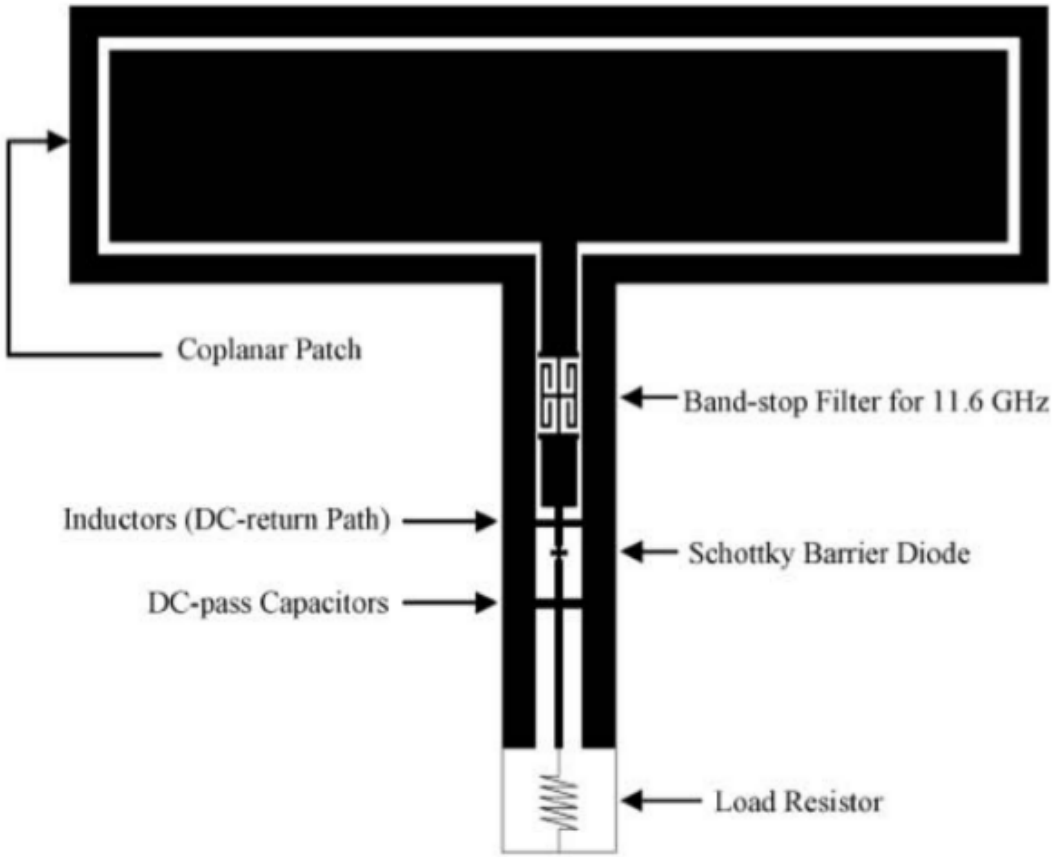


Figure : (a)Rectenna schematic; (b) Photograph of an LP rectenna.[2]

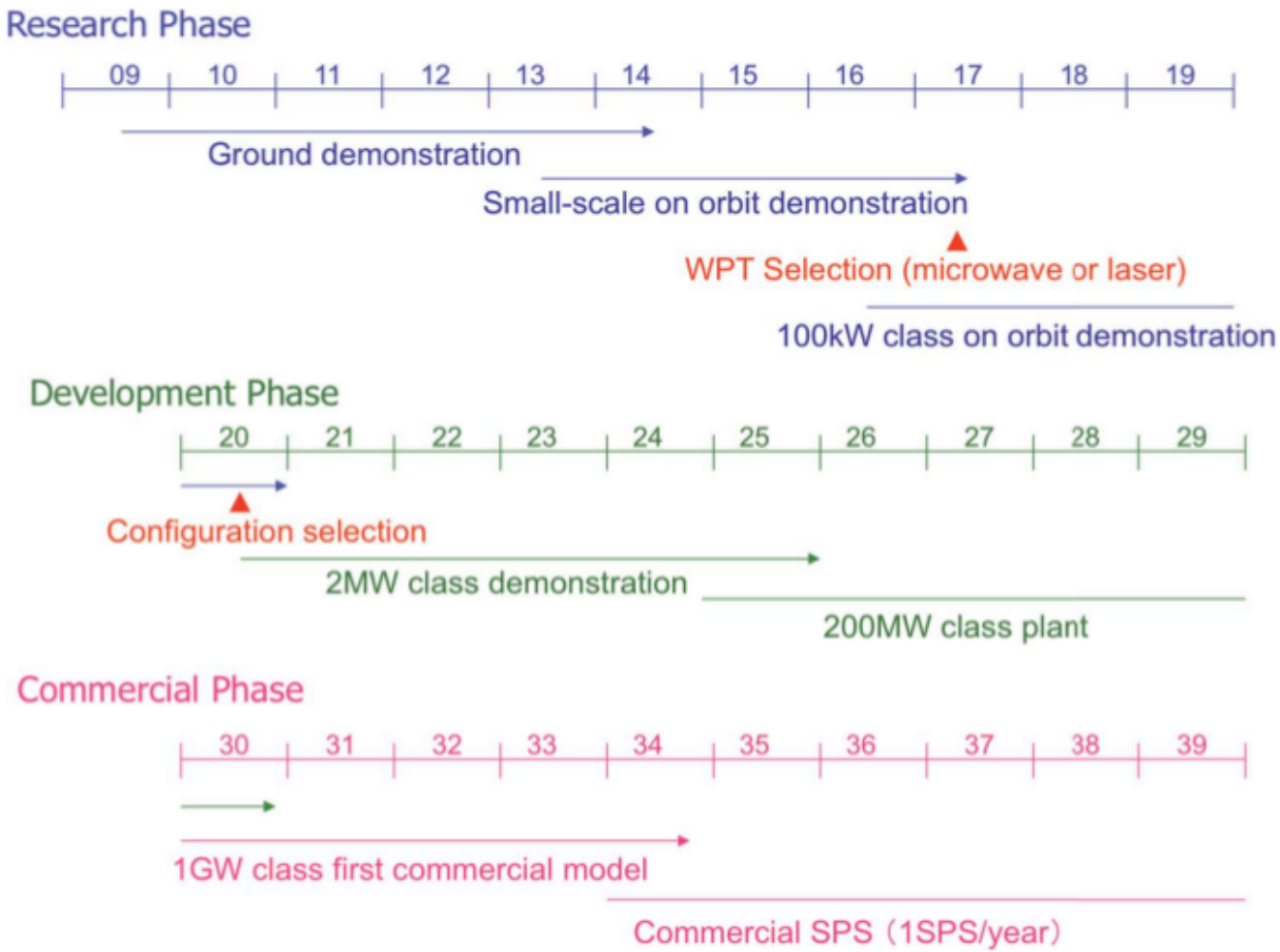
Recent Advance

A 5.8 GHz rectenna achieving 68.5% conversion efficiency has been developed at the University of Hong Kong.[4]



Roadmap for commercial SPS

Three phases: *research*, *development*, and *commercial* phase



Bibliography and Further Reading


S. Sasaki, K. Tanaka, and K. Maki,
Microwave Power Transmission Technologies for Solar Power Satellites.
Proceedings of the IEEE, Vol.101, No.6, June 2013.


B. Strassner, II, and K. Chang,
Microwave Power Transmission: Historical Milestones and System Components
Proceedings of the IEEE, Vol.101, No.6, June 2013.


Y. Homma, T. Sasaki, K. Namura, F. Sameshima, T. Ishikawa, H. Sumino, and N. Shinohara,
New Phased Array and Rectenna Array Systems for Microwave Power Transmission Research
IMWS-IWPT2011, 12-13, May 2011.


C. Chin, Q. Xue, and C. Chan,
Design of a 5.8-GHz rectenna incorporating a new patch antenna
IEEE Antennas and Wireless Propag. Lett., Vol. 4, pp. 175-178, 2005.