Beyond Chemical Rockets

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The amount of reaction mass needed to achieve a specific ΔV increases exponentially by the ratio of the ΔV to the rocket exhaust velocity. The exhaust velocities achieved by chemical rockets are considerably less than orbital velocity, which is why the fuel/payload ratio is so high for chemical rockets.

This also means that increasing the rocket exhaust velocity will exponentially reduce this figure. However, the energy needed to increase exhaust velocity also increases. Specifically, thrust is given by $F = mv$ for velocity v and mass flow m, and power is given by $P = \frac{1}{2}mv^2 = \frac{1}{2}Fv$. So for an exhaust velocity of 15 kps, 1 lb of thrust requires 5.11 kilowatts. It also takes only 1 lb of reaction mass for each pound into orbit.

Nuclear and laser rockets are still thermal rockets, and are ultimately limited by the melting point of the engines. The main advantage of a nuclear rocket (which runs cooler than a chemical rocket) is that it uses hydrogen as its reaction mass. Because of its lower molecular weight, hydrogen will have a much higher exhaust velocity than any other gas starting from the same pressure and temperature (about 3 times higher than H_2O).

The idea of firing a laser up the exhaust nozzle of a rocket engine is not well thought out, since it basically requires that the reaction mass be opaque inside the engine and transparent outside (not to mention the trajectory limitations). One could attach a laser target/heat exchanger to the side of a rocket, albeit with a significant weight penalty.

For even more significant improvements, I prefer a microwave powered linear induction motor.

A very large phased array could more than equal the aiming and focusing power of a laser. The rocket would have a relatively large (compared to the shuttle) delta wing which doubles as the rectenna array. This means that bottom (or top) of the wing must consist of a nonconducting material into which the rectenna array is embedded in addition to the heat shields.

One approach would be to place a series of power stations for several hundred miles in a remote arid environment (like Australia). A better solution would be to use a power satellite, since it is easier to beam microwaves down through the stratosphere than up through the troposphere. One satellite could also replace many ground stations.

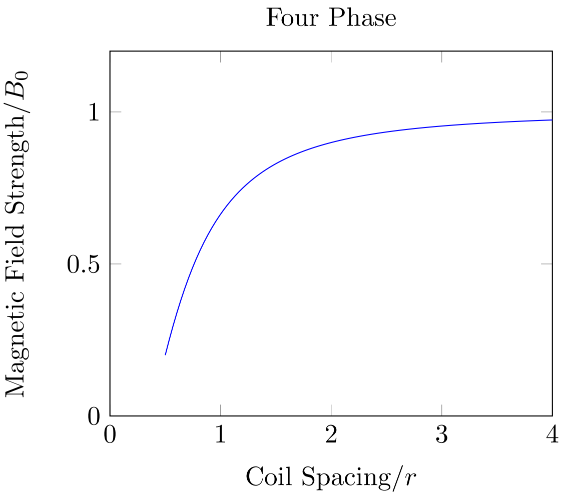
One could tile the entire rectenna area with bow-tie antennas. For each antenna one needs 4 diodes and one capacitor (or 2 of each). The main problem is that most of the energy will be absorbed by the diodes if the antenna voltage doesn't reach 0.7 V.

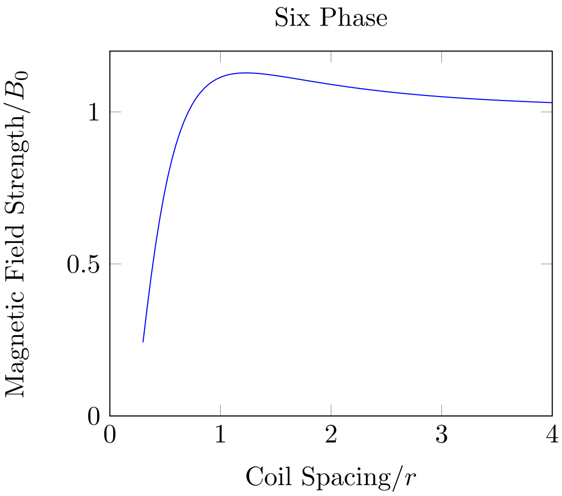
Mercury would be an ideal reaction mass if it were not expensive and toxic. About the only good conductors which are nontoxic are iron and carbon, but a mechanical loader is disaster waiting to happen. On the other hand, water will conduct electricity at microwave frequencies. This may consist of asymmetrical molecules spinning in place, but it still counts.

A frequency of 2.45 GHz (12.2 cm wavelength) with a coil spacing of 1cm (6 phase) corresponds to a phase velocity of 1.72×10^8 m/sec, which vastly exceeds any realistic exhaust velocity. If it works at all, it will work for any velocity, even with a constant coil spacing.

The force on a conductor in a moving magnetic field is proportional to the magnetic field strength and the relative velocity, and inversely proportional to the electrical resistance of the conductor. Increasing the number of turns in the coil/antenna does not increase the field strength for a given voltage. It will however reduce the amount of power wasted heating the coil.

The biggest problem will be keeping the reaction mass away from the walls at hypersonic speeds. Mostly this means putting a nozzle in the supersonic region and expanding the walls faster than the shock wave.





The coil spacing also influences the coil radius. The magnetic field strength at some distance d along the axis of a coil of radius r is given by $B = B_0/(1 + d^2/r^2)$ where B_0 is the field strength in the center of the coil. For a 4 phase system (90° between adjacent coils) at a given coil location the two nearest coils will cancel each other out, but the next two coils out will partially cancel the field strength at this location, and so on. The above graph shows the effect of coil spacing on field strength. The calculations include the effect of coils up to 6 spaces away for four phase and 9 spaces away for six phase.

Finite wavelengths help rather than hurt the coil spacing to radius ratio. For a wavelength of 12cm, 1cm corresponds to a 30° phase shift, so a three phase system with a 1cm coil spacing will have the same effect as a four phase system.