Reducing the entropy of the world

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Second law of thermodynamics says that “the entropy of the universe is ever-increasing”, the whole place is heating up, atmosphere soaking heat from innumerable sources of energy in the world. This will continue till we reach equilibrium called the “heat death” of the universe when all the sources of heat and rest of universe reach the same temperature. Obviously, it looks unlikely that life will survive beyond that point (it is debatable if life will survive even till that point, let us set that aside for another day). While this looks inevitable, we can be happy about the fact that such a time is so far away in the future that we do not need to worry about it.

However there are things that we need to worry about. We humans are aiding a rapid increase in the electromagnetic energy that surrounds us. Recent advances in wireless technology and corresponding explosion of data usage on air has put extreme demand on networks to provide more and more data. As the service providers respond, there is an increase in the electromagnetic footprint on mother earth. There have been many reports of harmful effects of such increased radiation in our surroundings. Understandably, there have been an increasing number of legislations across the globe restricting the total radiated power per unit area to keep a tab on the energy exposure of humans. While it has not been proven beyond doubt if the level of radiation is indeed harmful, it can be told in unambiguous terms that lesser is better.

Now, that is not good news for technologists like me who earn their living by developing products for wireless networks. The more our produce is deployed; the world’s entropy increases faster. Radiation exposure is higher, people might get cancer, bad things might happen, does not feel good, **unless…,** unless we do something about it.

To do something about it, we need to understand all these things, how much power is transmitted, what is received, how far from the tower, what about the phone sitting right next to my head and so on. In the following sections I try to explain these in a little more detail.

Let us consider a typical mobile tower covering a couple of kilometers of radius. For the sake of simplicity, let us assume that this tower has a single omni-directional antenna (an antenna transmitting with equal strength in all directions)[1]. It is easy to accept that the power received by an antenna at some distance from the transmitting antenna is usually lower than what was transmitted. Also, it is easy to accept that received power would be lesser for antennae that are farther from the transmitter. It is very important to understand that in free space, received power reduces as the square of the distance between the antennae. What does that mean? Say, I sent 1 watt of power from the transmitter, and say I received 1mW of power at a distance of 1m. I would receive 10uW at 10m, 100nW at 100m, 1nW at 1km and 100pW at 10km. Figure 1 shows the power received as a function of distance. What can be clearly seen is that the reduction in received power is rapid, even more than the increase in distance.

[1] Typical installations use three sectoral antennae which are directional. The number might be even more with the advent of MIMO systems

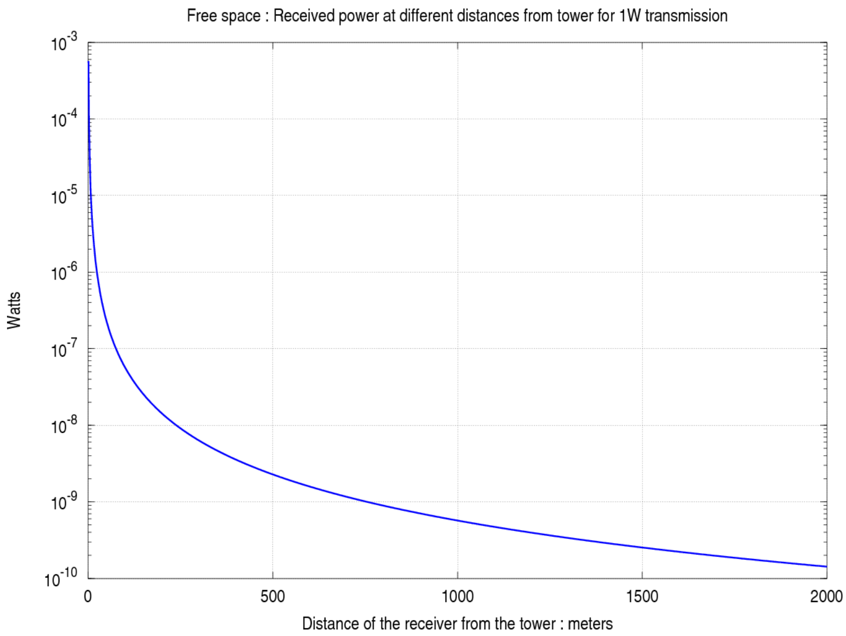


Figure 1: Power received in free space

This is even more drastic in urban terrain where the signal sees multiple obstacles in the path. The received signal power reduces as cubic or even higher order function of the distance. Taking the same example, if the power at 1mdistance is 1mW, 10m would now be 1uW, 1nw at 100mand 1pW at 1km. Figure 2 shows this phenomenon.

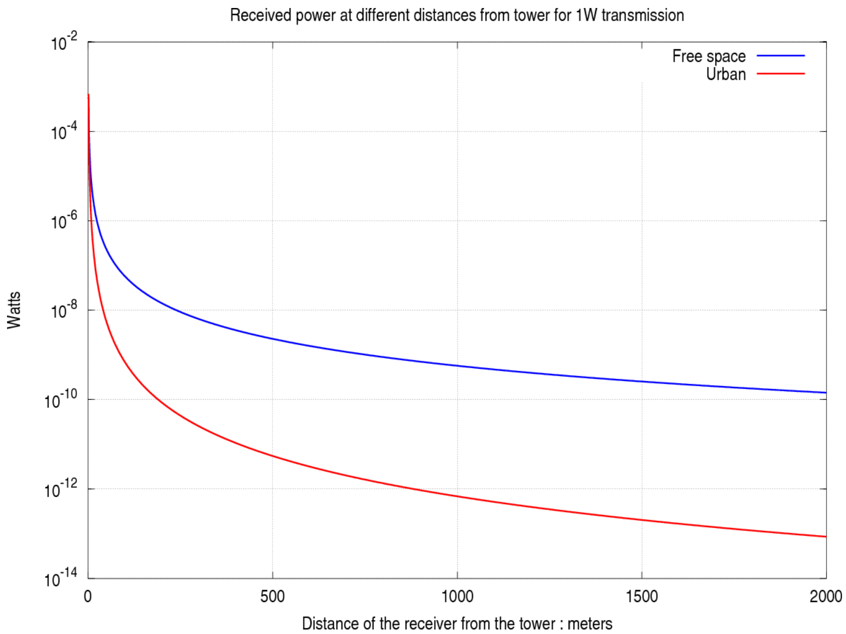


Figure 2: Power received in urban scenario

Now, let us consider a person trying to connect to network at some distance from the base station using his mobile device. Again, it would be easy to accept that there would be a minimum amount of signal power necessary at the receiver of the mobile device for it to work properly[2]. Practically, the receivers operate in a range of -60dBm to -110dBm corresponding to 1uW to 10pW. We can assume that if the signal received at the receiver needs to be at least 10pW (really small!) to make a connection (the device might connect at a very low data rate). So, now we saw in our urban example, when the transmitted power is 1W, there would be no connectivity beyond a radius of 460m around the base station. So, if we need connectivity at a radius of 1.5km, we will have to boost the transmitted power to nearly 40W!! Now that is what happens in real case[3]. Now, if you lived near the tower there could be a chance of higher exposure to this power (although, it comes down rather drastically in the first few meters as shown in the above two figures).

While these towers look big with visibly large antennae and give creeps to some people about the potential electromagnetic exposure hazards, there is a larger concern that lurks in our pockets. The cell phone! When one makes a call he transmits power to the base station which is far off[4]. Now, the base stations need a minimum power received at their antennae to maintain connectivity with the phone. The same argument presented earlier is valid here again. There are algorithms built into the system that ensure a minimum required power is always received at the base station. The power transmitted from the phone is higher if the base station is farther. By the same argument, phones should transmit tens of watts of power to reach the same distance. However, the base stations are designed to have better sensitivity and better antennae so that actual power transmitted from the phone is not more than 250mW. But, that is power right next to our brains!! Figure 4 shows this scenario. It can clearly be seen that the potential for exposure to electromagnetic radiation from your own cell phone is indeed much higher than that from the tower.

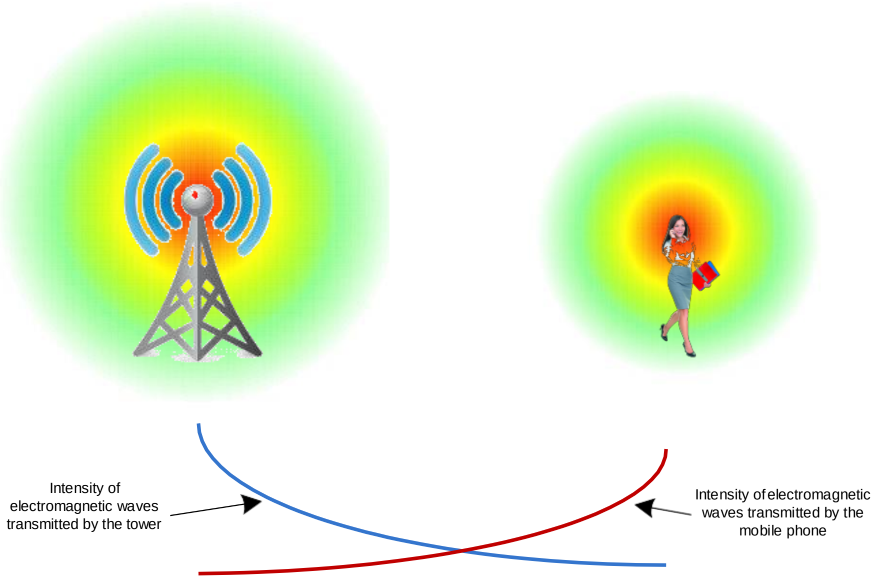


Figure 3: Exposure due to tower and own cell phone

[2]Technically this minimum required power is termed “sensitivity of the receiver”
[3]The numbers written here are a rough ballpark. Actual values vary based on particular installations
[4]Even when in ideal state, the phone does certain measurement/registration tasks in background

The Solution

As I mentioned earlier in the article, it has not been proven if this amount of exposure is bad to humans. Nevertheless a technology that could reduce it would be highly desirable. There are two major points of exposure

1. Power transmitted by the cell-phone affecting all users
2. Power transmitted by base stations affecting people that stay near the towers

The solution to this problem is to deploy more towers. Hey, we want to reduce the radiation and you suggest us to increase the number of towers? Yes. It would have been evident for if you followed the shape of the power loss curve with distance. Let us consider both the cases above

Power transmitted by the cell phone

This is very easy to prove. If the number of base stations in a given area is more, each cellphone is now closer to the particular base station it is talking to[5]. This directly means that power lost from phone transmitter to base station receiver is lesser. As a direct consequence, the cell phone transmits lesser power to maintain the same minimum received power at the base station. In fact the transmitted power could be significantly lower even for small decrease in base station distance since the path loss is typically a cubic or higher order function of distance.

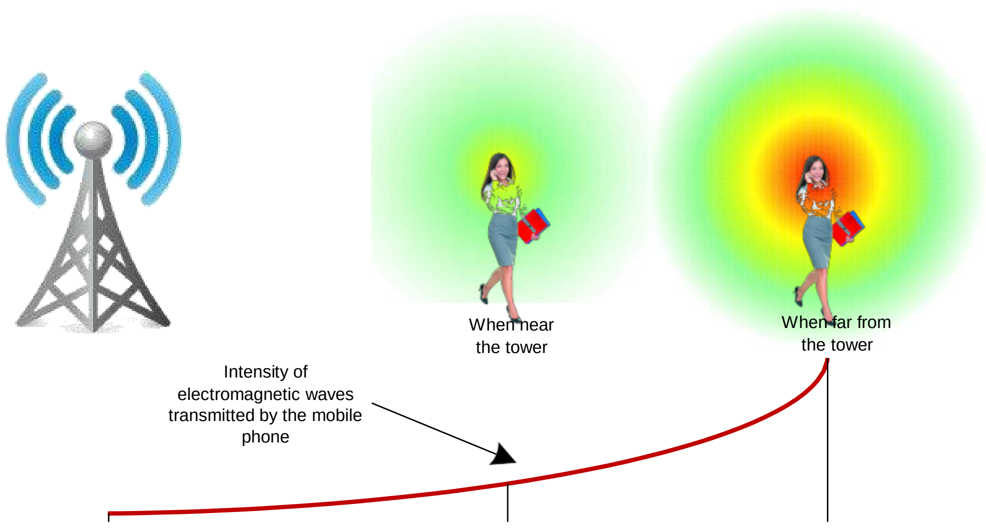
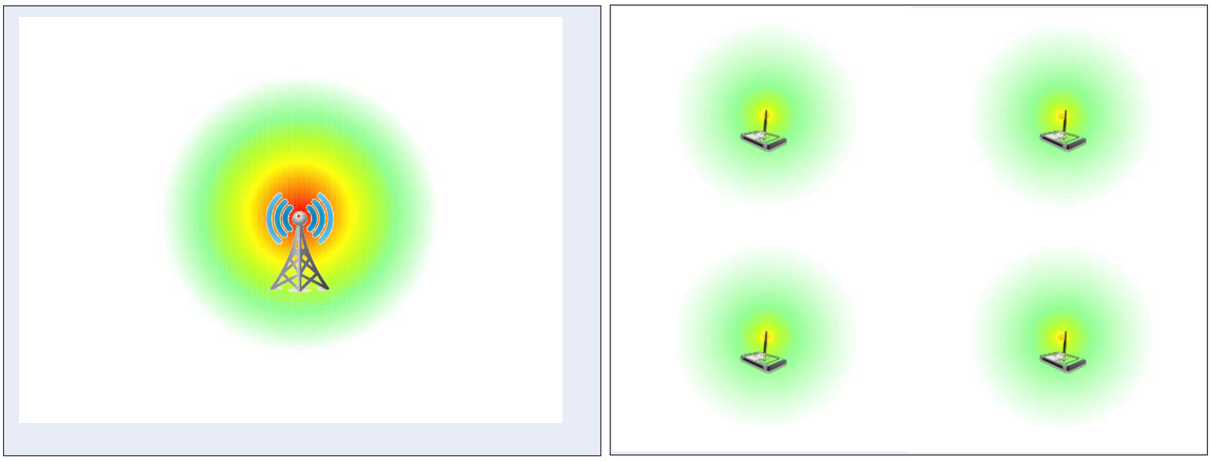


Figure 4: Own phone power reduction when nearer to the tower

[5]Cellphones have algorithms built into them that scan through all the nearby base stations and choose the one from which they are receiving highest power

Power transmitted by the base station

The same argument applies to the base station. We now have many small radius base stations instead of one large radius base station. Each base station now connects to lesser number of users who are also nearer now compared to the large radius base station. So the transmitted power per user reduces (and reduces significantly due to the exponential nature of the path loss curve). Directly, we can see that the farthest phone to the base station which caused the base station to transmit 10W of power earlier is now closer. So the peak power transmitted by each small base station is now significantly lesser. As we saw earlier, the real problem with base station power was near the tower where there was a potential for higher exposure. So, having multiple cooler cells removes this zone effectively. Figure 5 shows this phenomenon.



Radiation pattern around tower serving large area

Radiation pattern around multiple small towers covering the same total area

Figure 5: Transmitted power reduction due to increased number of cell towers

But, don't we have many more base stations now? What about the effect of the other towers? The transmitted power at the base station is reduced till such a point that the received power at the edge of the new cell with smaller radius is still similar to the power received at the edge of the old larger cell. So, the power exposure is lesser. In fact, due to the exponential nature of the decay in signal strength with distance, the sum of power from multiple base stations is fairly low even if the smaller cells attempt to provide higher power to the phones at the edge (and higher data rates[6]). Effectively we replace a red hot big base station with many cool small base stations!

Data rates:

While we analyzed the whole solution from an electromagnetic exposure perspective, we did not take a look at the quality of service and data rate aspect. What happens to data rate? Isn't

[6]Higher power at cell edge might not always mean better data rates since it interferes with the adjacent cells

that the whole reason why the exposure problem came up? Well, there is good news here. In fact the smaller cells were proposed to solve this problem. One of the main problems in wireless communication is that all the users share the same medium of transmission: air. They share the available spectrum[7]. When a lot of users in the same cell access the base station together, their data rate reduces. Now, having smaller cells mean reduction in the number of users that share the same bandwidth. Directly this leads to improvement of data rates, quality of service and everything.

So, small cells are clearly the panacea for all the woes of wireless communication. But then, if that is so, why don't we see too many of them? Actually we do see this trend for a long time. Historically, cell size has been reducing continuously. But, the data explosion we are experiencing in the recent few years requires a totally different thinking. The shift of tower mounted base stations to small equipment like Wi-Fi access points. That requires a rehash of the underlying technology. The base stations are no longer "infrastructure equipment" that could cost a large company thousands of dollars. They now need to be low cost, yet high performance boxes that can be installed in large numbers. Traditional chipsets that power these base stations are built to handle hundreds of simultaneous users and extremely expensive to sit inside small cells.

Signalchip has come up with extremely optimal chipsets that cater to this requirement. With its world leading foot print combined with ultra-high performance, Signalchip hopes to make the small cell revolution happen and hence reduce the electromagnetic exposure of humans.

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[7]Which is why a wired DSL connection feels better than an LTE connection with the same advertised speed