EMPS, Swarms and Other Types of Terrifying Technology

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Announcer:

Greetings. Electromagnetic pulses, or EMPs for short, are our hot topic for today. What are they? How do they work? What could they mean for our electrical infrastructure? And do they possibly have some defensive uses? Joining us, is Dr. Sarah Seguin, expert in the field of electromagnetic compatibility, who will help discuss these questions and more today on Mind Matters News.

Robert J. Marks:

Greetings. EMPs, or electromagnetic pulses come from lightning, the sun, nuclear explosions, and manmade weapons. We hear about EMPs disabling electronics. We hear that your cell phone would be wrecked and your car would be disabled because the electronics would be fried. And I tell you, as an electrical engineer, not specializing in this area, the more I look into this, the more concerned I become.

Robert J. Marks:

Our guest today to talk about this is Dr. Sarah Seguin. She is an expert in the area of electromagnetic compatibility. Dr. Seguin was formally on the faculty at the University of Kansas. She then developed the software business, Third Iron, and now is doing research at Baylor University. Sarah, welcome to the podcast.

Sarah Seguin:

Thank you very much. I'm really excited and happy to be here. I appreciate the time.

Robert J. Marks:

This is great. I think that we're going to scare a lot of people, don't you?

Sarah Seguin:

Well, I think that knowledge is power, and not necessarily scary.

Robert J. Marks:

Okay. Yes. I guess that there's truth in that also. Both you and I, are electrical engineers, and we are pretty diverse. The field of electrical engineering is, well in our parent's society, the IEEE, the Institute of Electrical and Electronic Engineers, has, I have to say this, over 400,000 members and it's divided into numerous individual specialty societies.

Robert J. Marks:

And one of them dealing with EMPs is subsumed in the society dealing with electromagnetic compatibility. Now, you're in that society. You've held office in the IEEE Electromagnetic Compatibility Society. And the study of EMP technology lives in this society.

Robert J. Marks:

Before talking about EMPs, let's be a little bit more general and just define what electromagnetic compatibility is, and why electrical engineers need a separate society to study electromagnetic compatibility. Could you describe the general field of electromagnetic compatibility?

Sarah Seguin:

Yes, I'd be happy to. It's a very large field. And a note that I am currently Chair of the Spectrum Engineering Committee, TC 6, Subcommittee of Electromagnetic, the IEEE EMC Society, Electromagnetic Compatibility.

Sarah Seguin:

So EMC, I always like to describe it the best when I was teaching the class at Kansas, basically electromagnetic compatibility, is based on the fact that all active devices radiate electromagnetic energy. And the fact that I am talking to you through my computer, and I have a cell phone right next to me, and my microphone is working, and everything is just working seamlessly, is electromagnetic compatibility. And it's non-trivial.

Sarah Seguin:

Basically, all of these devices, by just simply being turned on, radiate electromagnetic energy. And then this electromagnetic energy, we want it to not interfere with other devices. A very good example of an electromagnetic compatibility issue that generally like we've decided not to fix, because it's for cheap speakers is, I think all of us have set our cell phone next to an inexpensive speaker. And right before it rings, or maybe before we receive a text message, you hear a little bit of buzz, right?

Sarah Seguin:

Well, that's because those speakers aren't shielded against that energy that is being induced within that circuit from your cell phone. Now, of course, there's expensive speakers that can handle this. But the generally cheap computer speakers, et cetera, can't. So electromagnetic compatibility is basically the fact that we take for granted that all of our devices work together when we turn them on and there's no interference.

Robert J. Marks:

So a specific type of electromagnetic compatibility is the EMP, the electromagnetic pulse. What are EMPs? And I don't know, maybe you could discuss some of their sources.

Sarah Seguin:

Well, one of the biggest and most well known sources for electromagnetic pulses are nuclear detonations. So of course, a nuclear detonation, it has all sorts of physical issues. And when they were testing the nuclear bomb originally, and nuclear detonation in the mid 1940s, it was discovered that semiconductor devices that were used to monitor these effects were actually destroyed. But they weren't actually destroyed by the physical blast. They were destroyed by the electromagnetic pulse that comes before the blast.

Sarah Seguin:

Another source of electromagnetic pulses is lightning. And of course we can have created electromagnetic pulses. There have been some governments that have been working on that as well, that have been in the news recently.

Robert J. Marks:

Okay. Now, we hear that electromagnetic pulses fry our electronics, zap our electronic. What's the physics behind this? What is going on that a electromagnetic pulse can disable your cell phone or your car or something like that?

Sarah Seguin:

Well, again, it comes back to the whole electromagnetic compatibility issue here, and how hardened your device is. So what happens is you have a very intense, or powerful electromagnetic wave that's emitted from, for example, a nuclear detonation, or it could be created with electronics and a directional antenna. So then this intense electromagnetic wave basically causes current to be induced within the device.

Robert J. Marks:

I've always heard that, for example, your AM radio, as a result of electromagnetics being transmitted at the transmitter and you receive it. So it induces current and your radio.

Sarah Seguin:

Yeah. That's exactly what happens with AM radio, FM radio, all of it you're inducing current on the antenna that's receiving it. So an electromagnetic pulse is really just like a really strong transmission that's inducing currents on your electronics.

Sarah Seguin:

Unfortunately, it's in a way that we don't like, and the electronics generally aren't hardened for this or expected. Cause it could be antennas are definite problem places where a device could be vulnerable to EMPs. But in addition, just like, for example, if you think about a circuit board where there's a long trace to run currents across, EMPs could also induce currents there.

Sarah Seguin:

Now, inducing currents on a particular conductor is not necessarily the problem. The problem is when the semiconductors aren't rated for those level of currents that are induced. And then could actually physically cause these electronics to fry, like in the case in the early 1940s, when they discovered what was happening in their nuclear detonation tests or mid 1940s.

Robert J. Marks:

Yeah. In prepping for our conversation here, I read that Enrico Fermi, actually, anticipated this and asked people to cover some of their electronics prior to the Manhattan Project Explosion, which I thought was very insightful, let's talk about EMPs at a personal level. If an EMP goes off, we hear these fear things, will it fry my cell phone? Could it cut off communication between cell phones? In other words, screw up the infrastructure of communications, would it disable my car? Would it erase my flash drives in my computer memory? Are all of these true or some of them true?

Sarah Seguin:

Well, they could be true. It all depends on your proximity to the EMP. Because of course we know that the wave propagation decreases, the further away that you get from the source of the EMP. So if you're right next to the EMP, say a cell tower or your cell phone, your house, or for example, a lightning strike creates electromagnetic pulses too. That's a natural occurrence of electromagnetic pulses.

Sarah Seguin:

If you are right next to it, especially, if you don't your devices, aren't hardened to it for a lightning, for example, if it can conductively go through your power system and you don't have protection through surge suppressors, then the answer is yes. But from a like whole system standpoint, could it completely bring down an entire area? Well, it really depends on the strength of the electromagnetic pulse.

Robert J. Marks:

Okay. Yeah. You've spoken a couple of times about hardening the electronics. How do you protect your electronics? Say you wanted to protect it, you hear that there's a bomb which is going to go off that's going to generate an electromagnetic pulse. What do you do with your cell phone to protect it?

Sarah Seguin:

Well, you would want it to be preferably in a shielded room.

Robert J. Marks:

Okay.

Sarah Seguin:

But I don't know about you. I don't have a shielded room hanging around my house.

Robert J. Marks:

One thing that somebody suggested to me is microwave ovens. Microwave ovens are surrounded by a shell, a so-called Faraday cage, I believe that keeps the microwaves in. I think it should also keep the microwaves out. So I might go and put my cell phone in a microwave in order to protect it, and try to remember not to turn on the microwave oven while it's in there.

Sarah Seguin:

Yeah. You could definitely hurt your electronics and your microwave. But actually that's not a bad idea. Microwave ovens though, are designed to specifically shield at the resonance of water, because that's how they work. So it's 2.45gigahertz. And so in general it would probably do a pretty good job if you were far enough away from the EMP.

Sarah Seguin:

So it basically, if it shields for 2.45 gigahertz, that means that you shield based on the wavelength. So 2.4 gigahertz, the wavelength is about 12.5 centimeters in general, like the rule of thumb is you make the aperture or the holes, the largest size, for example, you can all look into your microwave about a quarter wavelength of that.

Sarah Seguin:

So in general, that's for the highest frequency, so it would be protected for everything lower as well, in general, you can assume that. And so I think putting it in your microwave oven could be a really good choice for your cell phone provided that other infrastructure survives.

Robert J. Marks:

One of the solutions I've also heard for protection is insertion of surge devices, surge protectors. The idea is that it's the quick change in the electromagnetic pulse that does a lot of damage. And maybe by using surge detectors, you could protect your electronics. Is that true?

Sarah Seguin:

Yes. It is definitely true. But you'd have to think about how the surge suppressor, what it's protecting against. So the surge protector is protecting against energy that comes from your outlets, or some cases people have whole house surge suppressors, some laboratories have whole building surge suppressors.

Sarah Seguin:

And so that assumes that for example, the electromagnetic pulse has, or lightning, which also got all those frequencies, it's an electromagnetic pulse of sorts. It induced current onto the power lines. And then it's means that these surge suppressors are protect against the large current that has been induced on the power lines from getting to your device. And then therefore, causing it damage through its power supply.

Robert J. Marks:

So this would only work if there was an EMP explosion and it affected say a power station that generated a surge on the line. If you were directly in the path of the EMP, it would fry your electronics and your cell phone directly. Is that right?

Sarah Seguin:

That's correct. Yeah.

Robert J. Marks:

Okay. Okay.

Sarah Seguin:

Well, it could. That is the part of the study of electromagnetic compatibility. Coming back to that is figuring out where devices are vulnerable. That's a whole study and then basically hardening them where they're vulnerable. So, for example, your cell phone is probably going to be more vulnerable at the frequencies that it receives.

Robert J. Marks:

Okay.

Sarah Seguin:

So it receives wifi at about 2.4 gigahertz. And so depending how close you are and how much of that frequency is in the electromagnetic pulse, for sure, you could definitely, if you are in the direct path of

that intense radiated electromagnetic energy, your devices could definitely be fried without being coupled through the power line. It just depends on where the energy is coming from.

Robert J. Marks:

Would an EMP destroy a flash drive, do know?

Sarah Seguin:

An EMP could destroy a flash drive, more likely it would probably wouldn't destroy the specific data that's stored. But it could destroy the electronics in which case you'd have to fix the electronics to recover the data. So for all intensive purposes, it is destroyed, the data.

Robert J. Marks:

Okay. Okay. I was having a conversation, I believe this was with a guy with Microsoft and we were talking about the best way to store files. And it used to be, you used little floppy disks, and then these floppy disks, you had USB ports that could have up to gigabyte on them. And now you can get them at terabytes buy them on Amazon.com.

Robert J. Marks:

And I found out that I tried to store some of my stuff on such devices. I went back in a year or two, and it was totally unreadable, I don't know where it went. But it just destroyed. And then along came rewritable CDs and DVDs. And I tried to store a lot of stuff on those, and that also in a couple of years, turned out to be no good. And he said that the best place probably, to store your stuff is on the cloud. And I'm wondering, and I don't know, and you probably don't know either whether the cloud is protected from these EPS.

Sarah Seguin:

That's a really excellent question. As a co-owner of a software company that he is in the cloud, I have a little knowledge of the cloud, but I am by no means as software engineer, or a data center engineer. So what's interesting about the cloud, is that in general, they have distributed data services, and these distributed data services means that your data's not in any one place.

Sarah Seguin:

And so by storing your data in the cloud, an EMP would have to capture everywhere that your data is. So it'd be unlikely. And in general, these data centers, I know for Amazon AWS, I think there's one in Virginia, in general, or at least somewhere out east, these data centers do have quite a bit of protection and security.

Sarah Seguin:

Now, is your data safe from hackers? That's a different question for a different podcast. But your data would be more protected from electromagnetic pulse by storing it in the cloud. That's for sure.

Robert J. Marks:

Yeah. I had heard this too, that Microsoft has three or more centers and they would have it on the east coast, the west coast in the south. I should have looked, I should have looked this up, but I didn't. And that there is a redundancy there. And that if you lose one of these sites, well, you can still regain your

information from another site. So they might be doing that instead of electromagnetic compatibility hardening. It's just a thought.

Sarah Seguin:

I think they do a little bit of both. I have known folks who work for IBM, who work in their data centers. They also have big data centers in the cloud as well. And in general, they are concerned about electromagnetic compatibility. They do employ EMC engineers. I know folks who work there or have worked there.

Sarah Seguin:

And so they do harden them a bit just by the fact that these really industrial servers just need to be hardened to work in a large room with a ton of servers. So it's kind of a combination, but I imagine they don't necessarily have military protection, if you will.

Robert J. Marks:

In 1989, our own sun electromagnetically disrupted the US power grid. Something scientists call a coronal mass ejection, CME, from the sun was about the size of 36 earths. And it erupted from the sun's surface. It set off a geomagnetic super storm. The result was what scientists called geomagnetically induced currents on earth.

Robert J. Marks:

These electrical surges infiltrated power grids all over north America and Northern Europe, and even destroyed a transformer at a nuclear power plant in New Jersey. Even more seriously. Canada's Hydro-Quebec Power Grid, crashed when the safety systems sensed the power overload caused by the ground currents. The failure knocked out electricity to six million people in Northeastern Canada for as long as nine hours.

Robert J. Marks:

Now, this was nature. EMPs come from manmade nuclear explosions. Here and there, we hear about EMPs from nuclear explosions, frying the power grid, and all of our electronics, a worse case scenario was reported by a federal committee called the National coordinating Center for Communications, the NCC, this is a 2019 report. They talked about high altitude EMPs, and you take the H from high altitude and then put in the EMP and you get a hemp.

Robert J. Marks:

So they're talking about hemp risks and this is a quote from their, from the report. It says hemp disruption and damage to critical infrastructures can occur across multiple time zones with one or more nuclear bombs exploded at high altitudes in the near region space, a single nuclear burst 250 miles above Kansas could destabilize much if not most of the US power grid. Likewise, one hemp burst over North America could significantly disrupt regional or continental data infrastructure such as the internet and our television radio phone and cellular networks." There, the quote ends.

Robert J. Marks:

Now, an explosion 250 miles above the earth is about as high as the US space station is from earth. So the EMP just described would need to be detonated in outer space. Now, no one wants to militarize

outer space. But as I point out in my book, The Case for Killer Robots, cases like this can result in threats from our adversaries and unfortunately forced the issue. This is one of the many reasons former President Donald Trump, formed the United States Space Force, as a separate branch of the United States Military.

Robert J. Marks:

And this is not theory. This is not a bunch of physicists scribbling on notepads with the equations. There's experimental verification. We know EMPs from nuclear explosions zap electronics. A 1962 test of a 1.4 megaton bomb exploded 250 miles above the Pacific Ocean disrupted global communications, and blew out street lights on the ground in Hawaii. There weren't many satellites in 1962, but the explosion zapped some of them that were there, this included the British Ariel 1 Satellite and a US, A Telstar Satellite.

Robert J. Marks:

So today, we know that GPS is controlled by satellites. And so a thermonuclear bomb, 250 miles above the earth would destroy a lot of the satellites that's responsible for our GPS. This is one of the reasons, by the way, we have nuclear test ban treaties. I used to think that nuclear test ban treaties were put in place so that people would didn't develop thermonuclear bombs anymore. Well, that's probably one of the reasons.

Robert J. Marks:

But another one was, every time you exploded one of these bombs, there was EMP effects in different parts of the world. Now, here comes the chilling part, Russia and China, both have the technology to detonate an EMP from space. EMP threats from US adversaries from less developed countries like North Korea and Iran would have to be detonated closer to the ground. But nevertheless, could do severe damage.

Robert J. Marks:

So I want to talk about EMPs specifically in the power grid. An EMP miles above Kansas, above your former employer, University campus could wipe out the American power grid according to this report, more realistic EMPs from US adversaries would not be that powerful. It just in general, could you give us an overview, how vulnerable is the United States power grid to general EMPs?

Sarah Seguin:

Well, it's really hard to know the answer to that question, unless you're this specific power grid. So when I was looking into this a little bit, it really depends on the specific power grid, but in general, if you think about how easily an electromagnetic pulse could couple into power grid, well, all you need is a really good conductor.

Sarah Seguin:

Well, what do you need in the power grid? Well, to get electricity to folks, you need really good conductors. And we have them,. Many of them not buried. The lines that are buried would have a little better shielding, but the ones, of course, for really long lines, we bury our electrical lines in large cities and newer cities, of course. But if we're running them for really long length, we're running them across fields and they're in the sky if you will. I mean, above the ground, anyways.

Sarah Seguin:

So it really depends how each individual power transmission grid is hardened for electromagnetic pulses. And in the process of doing some research, I found a report by NRECA, which is one of America's co-op. These electrical co-ops are places that basically take care of power distribution. You have your power company, they do the generation of the power, but then there's these various cooperatives across the United States, that then basically, figure out how to distribute this power, which is very non-trivial.

Sarah Seguin:

Anyways, their conclusion from a 2019 report was that an electromagnetic pulse would not have widespread impact on the electrical grid. Now, I actually tend to agree with you that an electromagnetic pulse put in the right place, knowing certain vulnerabilities of, for example, certain local power distribution centers could take down a large portion of the grid. You would definitely want to go through city centers to have the most impact.

Robert J. Marks:

When we drive by these power substations, I look over and again, I'm not an expert in the field, but I don't see any shielding there. I don't see any protection.

Sarah Seguin:

Yeah. So there's one not too far from my suburb. And I find it super fascinating. I don't know if they caught me looking one day, but they've actually recently covered. They've recently covered the fence so I can't look in. But I find them super fascinating. And actually, when I'm just driving down the road, I love looking at these power lines and figuring out, now they mount cell towers on them as well.

Sarah Seguin:

And in general, I think that are more concerned with lightning. They're probably more hardened for something like lightning. But the actual terroristic threat, I don't think that they have spent too much time hardening the grid for that.

Robert J. Marks:

That's a little bit scary. I, in also prepping for this podcast, I ran across an article in Forbes, and this was published in June, 2021. So it wasn't that long ago, there was a federal committee called the EMP Task Force on National and Homeland Security, and they issued a scary report specifically on China's ability to conduct an EMP attack on the United States.

Robert J. Marks:

Now, according to Forbes, China, now has super EMP weapons. And again, they might be in outer space, they have satellites in outer space. They also say that China knows how to protect itself against an EMP attack, so I have no idea what's happening in China. But apparently, according to Forbes, they're doing things about hardening, their power grid, and they have developed protocols to conduct a first strike attack on the United States.

Robert J. Marks:

It would be a devastating Pearl Harbor sort of incident should they ever choose to do that. That's just chilling. Do you know if there's been any proactive attempts to protect the US power grid?

Sarah Seguin:

I am not privy to that information. Because there have been some recent reports identifying the issue, I think that there has been some discussion. But are we putting funding into it? I question that, I think we should be though.

Robert J. Marks:

Yeah. Hopefully. What's the physics behind EMPs frying the power grid. One of the places I believe is transformers. I hear a lot about EMP taking out transformers. What's the physics that happens that zaps transformers with EMPs?

Sarah Seguin:

So you talked about China and possibly even they might have satellites that could direct the energy, which is very terrifying to me too. And I can think about it actually being possible. It'd be expensive. But certainly for someone determined, it may be possible. Honestly, you could build something where you're just a person walking by with some dedicated antenna as well.

Sarah Seguin:

And in general, what the physics is, is it creates a very large electromagnetic wave that then is designed to couple into these transformers, and these substations very well. So you would know in general, how the substation works, and you'd create a frequency that would couple in well. And then you can literally induce the currents from that electromagnetic wave that then could actually just completely take out the electronics. And transformers, the big problem is the way it... I mean, you're an electrical engineer, you know how a transformer works, right?

Robert J. Marks:

Yeah. I know enough to be dangerous. Yes.

Sarah Seguin:

I think that's all of us. Right.

Robert J. Marks:

That's true. And so I'm wondering if the transformers, it's just a thought, I don't know if this is what happens, but I would imagine that the wires would get so hot they would melt the insulation and everything would be shorted out.

Sarah Seguin:

Right. I think that would probably one of the main mechanisms. It would just have this huge current induced that then, yeah, it shorts it out and then once it's shorted out, then nothing's going to work. And also you'd have big currents induced across the grid that way. And then you could, take out other people's electronics near the substation as well.

Robert J. Marks:

Now, we think about EMPs originating from big nations like China and Russia, and also from smaller countries, North Korea, and potentially Iran. So this brings up the topic of terrorism. How much would a small EMP device cost a terrorist that wants to do some damage?

Sarah Seguin:

Well, I think that you could probably do it for several thousand dollars and do a very directed EMP to something like the power grid, or some building that you were trying to... I don't want anybody to knock on my door. Because I'm definitely not thinking about doing this.

Robert J. Marks:

Okay. Okay.

Sarah Seguin:

But you could definitely do it for several thousand dollars. And you could direct it to a specific building just in the way that other terrorist attacks have been directed to specific buildings or specific stations in the past.

Robert J. Marks:

Okay. That's a little bit scary. Now, for a few thousand dollars, if you could build an EMP, we're not talking about explosions here, thermonuclear bombs going off, rather we're talking about super antennas, if you will. Is that a fair statement?

Sarah Seguin:

Yeah. This is not talking about having any nuclear material. This is actually creating a very specific device that you know would affect the electronics that you want to affect. For example, we've read that Russia has created something, which is basically a directed electromagnetic pulse for taking down UAVs at specific microwave frequencies.

Sarah Seguin:

So what you could do, you would have to have some prior knowledge of the substation you wanted to take down, or the building. But you could very specifically, having some knowledge, which wouldn't be very difficult to get, spend many thousands and do some major damage if you chose a significant, important target. And of course I could name any number of those. And so could anybody listening to this podcast but we would hope that no one would.

Robert J. Marks:

Hopefully, but our adversaries sometimes are very creative. Getting back to the power grid, there is, as we mentioned, a lot of talk about improving the infrastructure in the United States. And one of the questions is what would it take to harden the US power grid? And I read one source and I don't know about the validity of the source. There's so much fake news out here today. But this is from a place called the Foundation for Resilient Societies, and we will provide links on the podcast notes to a lot of the articles that we referenced here. So you can go and check out and verify this.

Robert J. Marks:

But one source says that the first order cost model would be an overnight cost of EMP protecting the US bulk electric system to be on the order of 255 billion dollars. Now, when people get into billions and trillions, I think that they begin to lose focus on what that means.

Robert J. Marks:

We are about trillion dollar stimulus packages. And if you look at that, how much is a trillion? Is it bigger than a billion? Yeah, it's a thousand times bigger than a billion. But what does that mean? Well, $1 trillion dollars, if we divided it between the 328 million people in the United States is over $3,000 per capita. So if we were to have the United States citizenry pay for that one trillion dollars, then each of us would have to each man, woman, and baby would have to cough up $3,000.

Robert J. Marks:

And so in order to fix the power grid, this one source says that it would be $776 per capita. And they're talking about 255 billion. So we have a long way to go. And that's scary. Finally, Sarah, how scared of you are EMPs and the vulnerability of the United States to EMPs? As a specialist in electromagnetic compatibility on EMPs?

Sarah Seguin:

I am worried. I think that we should put some funding after hardening our electrical grid, and other important targets such as, certain buildings, for example, government buildings, to make sure that in the event of an electromagnetic pulse, if we truly are just going for the electromagnetic pulse and not like one attached to an explosion, which of course there's other issues associated with that. I think that we should be putting some funding after that.

Sarah Seguin:

And I am worried. But do I sleep at night? Well, yeah. I mean, there's all sorts of things to worry about that are scarier than electromagnetic pulses.

Robert J. Marks:

There are so many things to worry about. You got to pick one and work on it, right?

Robert J. Marks:

One of the uses of EMPs is defensive. And I'm pretty excited about it, because it answers a question that I've had for quite a while specifically, how do you deal with drone swarms? EMPs can be in the microwave frequency range, microwave ovens don't use EMPs, but the microwave radiation is contained to the oven by a Faraday cage. A Faraday cage is a metal surrounding that keeps the microwaves inside. It can also be used to keep microwaves from the outside, from getting in.

Robert J. Marks:

One question, not about specifically EMPs, but just in general, microwaves, can a steady dose of low power microwaves, not a pulse, but just a slow continuous exposure to microwaves, make us sick?

Sarah Seguin:

It can. And there have been some studies which you can even go to PubMed yourself and look up things like Havana syndrome and look at it yourself. So the reason being, is microwaves actually work by the

fact that they operate at the resonant frequency of water. Which is 2.45 gigahertz. And water is a polar molecule. And basically what happens is these microwaves generate electromagnetic energy at 2.45 gigahertz, and they have mixers that send it all over the metal cavity of the microwave. And then while these electromagnetic waves are bouncing around the cavity of the microwave, the polar molecule that is water will basically want to continuously realign in itself, which with the electromagnetic wave.

Sarah Seguin:

And so this water molecule moving around, then causes the food to heat up, which is why if you put something that's not really high in water into your microwave, it doesn't heat up. So how does that relate to the human body? Well, I am not a physician or medical doctor, but in general, most figures out there say that we, as humans, are made up of what, like 80% water. And so continuously realigning our water molecules and heating us up could have very bad effects on us.

Robert J. Marks:

Okay.

Sarah Seguin:

But 2.45 gigahertz, does that sound like a familiar frequency to you as well? 2.4 gigahertz is actually wifi, right? So then you're like-

Robert J. Marks:

Oh, so I wonder if people have done this research into putting cell phones next to your head and cell phones, of course, work on microwaves at the same frequency as your microwave oven. And is that going to fry your brain? Is that?

Sarah Seguin:

So at the power levels in general, like for example, one of the conferences I always go to for IEEE the EMC [Symposium 00:37:12], they do have papers on this sort of thing. And you can Google for papers, go to Google Scholar or whatever for papers on this sort of thing. In general, at the power levels that we are subjected to by our wifi, by our cell phones, in general, they probably aren't going to hurt us. Although, the jury still's out, they are still doing studies about that.

Sarah Seguin:

But if you were to just increase the power a bit more, it has been connected with all sorts of possible brain injury, unfortunately. So yes, microwaves can damage a human, but it has to be at the right power levels. At least that seems to be the answer in the relevant literature right now.

Robert J. Marks:

Interesting. Yes. You mentioned, I think the Havana studies, where I think it was Russia, is suspected of using microwaves in Havana in 2016, to make some of the US ambassadors sick. And that's where the Havana thing came from. One of the things I read in a Forbes article, the Forbes article was entitled, The Pentagon Fears That Deadly Microwave Weapons Are Undetectable.

Robert J. Marks:

It says that the US is concerned because the radiation that makes us sick, the microwave radiation is hard to detect, is this right? Can you detect these low doses of microwaves? If, say for example, I'm in an embassy somewhere, and I want to detect whether some adversary is zapping me with a continuous stream of microwaves.

Sarah Seguin:

So when the news originally broke, I've been kind of fascinated about this myself, about Havana syndrome. And then I kind of dug in more to it. I was fascinated with like, "Can we detect this?"

Robert J. Marks:

Mm-hmm (affirmative).

Sarah Seguin:

And the answer is, is I actually think that we can. I think that we could make little sensors that are the size of a cigarette pack, if you will, or a gum pack, maybe a little larger a couple of gum packs. And that if you kept it always on, it could maybe have for example, a warning when electromagnetic waves, particularly, microwaves went above a certain level.

Sarah Seguin:

And so I read that Forbes article as well. Thank you for giving me that Forbes article, but I disagree. I think that we could build detectors. And for example, it seems like what Russia is suspected of doing, or some other combatant is that they deliberately focus the energy at the building probably. So it seems to me, you could also put certain detectors in a building. Because certainly, microwaves that don't hurt us, like with our cell phones, those are measurable. Because if they weren't measurable, we wouldn't be having cell conversations. Right?

Robert J. Marks:

Exactly.

Sarah Seguin:

I won't talking to you over the wifi. So when I read that I was very skeptical. I mean, of course maybe they know something I don't. And I'm sure they know a lot that I don't. But I do think that you could build a detector and I'm kind of fascinated with the possibility of doing that.

Robert J. Marks:

Yeah. Yeah. You make a good point. If we already have microwave detectors, except they're not used for detectors, those are our cell phones. They receive signals that are microwave frequencies. And our phones can detect them. So why can't we monitor and detect signals at a higher level? The ones that make us sick?

Sarah Seguin:

I would certainly think you could. Apple, I think locks it out the last time I checked. But in general, you could get an Android device and put on a better wifi, or they do already have wifi antennas, and you can see the levels. You can walk around your house and see the levels of the wifi. And find, for example, if

you wanted to make your wifi better, find the low spots or the high spots and put repeaters where the low energy is.

Robert J. Marks:

Yes. I was doing some research with our mutual friend, [Charlie Bailis 00:41:10], and we went out to the Waco Airport, and we turned on one of these devices that not only detected it, but could identify the cell phones. It was really spooky. Because we walked by and we got one name just out of the air. And we said, "Wonder who this is?" So we Googled it and we found out he was a student at Baylor University. I mean, it's scary if they could detect that they should be able to detect microwaves that hurt you. So yeah. I totally agree with you.

Robert J. Marks:

So back to EMPs, we know that the low level microwaves can have a long term effect on you. What about an EMP? Well, an EMP, which is a pulse, as opposed to a steady dose of microwaves will that have an effect on humans?

Sarah Seguin:

Well, you made a really good point. Humans are really resilient. I mean, that's why we've done so well over the years. And so in general, what happens and of course, as I said, I'm not a physician, but in general it's time to exposure. So an EMP would be a very short event. I mean, unless you were at the source of the EMP, that might be different. But in general, for a very short event, people are probably going to be just fine.

Sarah Seguin:

The microwaves affecting those people, it was very long term exposure at higher than normal microwaves that would normally be propagating around your house for wifi, or for your phone or whatever. But it was for a very long period of time. Whereas, an EMP, the whole idea behind it is, it's a very brief event that causes large transient currents to be induced on the devices that are affected.

Robert J. Marks:

Okay. And so we wouldn't have large currents induced in our biological selves is probably the answer, right?

Sarah Seguin:

Yeah. Probably not. Like I said, though, if you were right next to it, there is a possibility that an EMP could have an effect. But in general, over the widespread area that it had an affect, I don't think so.

Robert J. Marks:

Okay. Well, let's talk a bit about EMPs and warfare. Clearly, anybody that has a capability of doing a thermonuclear bomb, is going to be a potential source of EMP in a warfare scenario. There are also missiles, I understand which be launched, and detonated and their detonation gives a smaller EMP sort of pulse. So we have these bullets that we can aim towards people and things like aircraft carriers, and they would have an EMP effect.

Robert J. Marks:

Aircraft carriers are awesome tools of warfare, but in modern hot warfare, when high tech missiles are exchanged, aircraft carriers are sitting ducks. Their entire purpose is to sit there and get the planes in the air, then they will probably be destroyed and sunk, unfortunately.

Robert J. Marks:

But with the EMPs, we get a different sort of story. There's a potential that EMPs can take out the planes by disabling their electronics. What can EMPs do to, for example, aircraft in the air?

Sarah Seguin:

So we are fortunate to some extent that aircrafts would not fly without some hardening to electromagnetic pulses. Because they have to be hardened into things like lightning. Lightning of course, is basically a natural phenomenon that creates electromagnetic pulse. So of course, now, the people creating an electromagnetic pulse would know that these aircraft have some hardening to lightning. And probably I, imagine electromagnetic pulse, because if we're talking about military vehicles or are we talking about passenger?

Robert J. Marks:

No. We're talking about military vehicles. Yes.

Sarah Seguin:

Okay. So when it comes to military, they already do build a lot of that. There's various military standards. But are they still vulnerable to electromagnetic pulses if they were made to directly target them? Yes. And they are particularly vulnerable. Because they're in the air and if their electronics just stopped working, especially, for something like a helicopter, that doesn't have any sort of like natural help to stay in the air, it would just fall out of the sky.

Robert J. Marks:

Like a rock.

Sarah Seguin:

Yes.

Robert J. Marks:

One of the other things that we have in the military, in our tool chest, is submarines. And they are probably the most stealth of all warfare tools. They are under the water and you can't use radar on them. Cause electromagnetics doesn't go through water. I've heard it described as the same thing as a laser pointer, shined through a glass of chocolate milk. It doesn't go very deep into the chocolate milk. It just attenuates and nothing happens. That's a reason that we use sonar underwater as opposed to radar.

Robert J. Marks:

So the question arises now, will EMPs work on a submarine, will submarines be disabled by EMP blasts?

Sarah Seguin:

The answer to that is generally if they're under the water, they'll probably have some shielding, and have some protection. However, there is some vulnerability that someone could know with knowledge, create an EMP that could possibly affect a submarine. For example, when a submarine is surfaced, that is not its natural state from a design standpoint. And then, for example, if some people were out on the deck while it's surfaced or something, then you have more openings and also a direct path that is not... We'll call the water, having, the way you said sort of a shielding effect, if you will. It doesn't have the water to shield it from that electromagnetic energy. So if it is surfaced or possibly if they knew while the periscopes? [inaudible 00:47:16]-

Robert J. Marks:

Yeah. Periscopes. So let's talk about periscopes. If there was a periscope, could the electromagnetic pulse go down the periscope and hit the submarine?

Sarah Seguin:

It possibly could. It would depend on how the periscope is designed. I'm certain that there's some really smart folks designing submarines, group of folks, if you will. So they probably do think about things like that. But it could be designed. Or for example, perhaps, you could create a missile that is not designed to actually do damage to the submarine, but just get close enough to the submarine such that you could make it subject to an electromagnetic pulse.

Sarah Seguin:

Now, the thing that we have naturally working for us, in the case of a submarine and hardening towards electromagnetic pulses, is the fact that it's just a big metal box that in order to survive the pressures of the water, it's basically welded and connected really well. Well, it turns out that also makes a really excellent shield to an electromagnetic pulse.

Sarah Seguin:

But if you could Pierce it just a little bit, say not enough damage to sink the submarine, but pierce it enough to get inside that shell, then you could create an electromagnetic pulse that went off to affect the electronics. So there a little more immune than for example, airplanes, but there could be a possibility for a creative electromagnetic pulse that could affect a submarine. But highly unlikely,. There are lots of other easier ways to affect it.

Robert J. Marks:

That's fascinating. We have a colleague at Baylor, Dr. [Eric Blair 00:48:56], who served on a nuclear power submarine, and he would go down under the water for long periods of time. Total blackout. No news, no communication. And nobody knows where these submarines are at. It is incredibly stealth. I want to talk about swarms a little bit.

Robert J. Marks:

One of the things that I raised in my book, The Case for Killer Robots, is the most chilling, I think of application of artificial intelligence. And that is autonomous swarms of drones. And the problem with swarms is they're hard to destroy. You go kick over an anthill and you stomp and kill most of the ants. You come back in a week and that anthill is rebuilt. You got to get them all in order to destroy the total anthill, the total swarm. It's the same thing with swarms of attacking drones, you have to get them all. And if a few sneak through, they can still accomplish the mission.

Robert J. Marks:

And if they're autonomous, it's really scary stuff. If you want to get some chills on what swarms can do, watch the movie, Angel has Fallen, with Morgan Freeman as the President. It has in the beginning, an attack of one of these drone swarms.

Robert J. Marks:

So how do you defend against these things? Well, one of the things you can do is have dog fights that is launch your own defensive swarm and have them go up and engage these drones one at a time. But I tell you, doing that would require some really heavy technology, and would be very expensive to do.

Robert J. Marks:

Israel, has developed a laser weapon that can take a drone out of the sky, but one drone at a time. So you'd need a lot of these laser weapons to take the drones out of the sky. And I always wonder how these laser weapons would work on a cloudy day. I'm not sure what they do.

Sarah Seguin:

I think they'd have troubles.

Robert J. Marks:

They would have troubles. Now, Sarah and I, Dr. Seguin and I talked way before it was announced that Russia had come up with the solution. She had the idea of using EMP weapons. Now, this would not be a thermonuclear explosion. This would be I believe like a super Ray gun that you could point towards a swarm and totally disable them.

Robert J. Marks:

So Sarah, how would a Ray gun that you could aim at a drone, a swarm and take out all the drone swarm. How would did that work? Do you think they'll be effective?

Sarah Seguin:

I think that they could be effective. But generally, probably, have to be in very close range I think, of the drone swarm.

Robert J. Marks:

Oh, because of the attenuation of the beam as it goes out.

Sarah Seguin:

That's correct.

Robert J. Marks:

The spreading. Okay.

Sarah Seguin:

Yeah. Yeah. Cause as it propagates, it's going to attenuate quite a bit. What's interesting is that it's definitely possible. And you could just say that you don't, or you aren't concerned with the biological

cost. So definitely at these high levels, humans if they were exposed to this, or animals, would probably have some effect. Because they're literally just radiating a large amount of electromagnetic energy towards this.

Sarah Seguin:

And in general, because it's not associated with an explosion, they probably have to give it a larger amount of exposure time to induce the currents to cause these electronics to fault.

Robert J. Marks:

I see.

Sarah Seguin:

Obviously, there's a human cost if you're under attack from a drones swarm. And there's a worry of various assets that you want to protect. But also to create that amount of energy, you can definitely direct it, but it's only so directional, as anybody knows, who's tried to shield electromagnetic energy, it's definitely or tried to propagate it, it's still going to propagate behind it and around it.

Sarah Seguin:

So I think that it is possible to create a weapon. Of course, it's a lot easier to create one if you know the specific vulnerabilities of the drone. But the idea is that you need a defensive system that doesn't know the vulnerabilities of the drone.

Robert J. Marks:

Okay. And then in the next step of the arms race, it would be hardening the drones. But hardening the drones would increase the weight, and therefore, the mobility and the time that the drones can spend in the air. Right?

Sarah Seguin:

Yeah. One easy thing that you can do, for example, what they do now to airplanes that are made out of carbon composite to help part in them for lightning, for example, is they use metalised paint. And so that is definitely one thing you can do, is sort of like if you will, spray paint, it's a little bit more complex than that. Cause you need a certain amount to shield, et cetera, et cetera.

Sarah Seguin:

But if you were to basically use conductive paint on these, but even that, for a drone, which in general is going to be extremely light, that's going to add an amount of weight that might not be acceptable as well. So I think the idea with a swarm is that you just build a bunch of cheap things that in general you know it's vulnerabilities. But it'd be very hard to, for example, with a directed electromagnetic energy that you could bring them all down with. So it's about overwhelming the weapon.

Robert J. Marks:

Oh my goodness. I mentioned that you and I had talked about this a while back. And we're begin to think seriously about it. It was totally your idea. But then there was a Forbes article, entitled, Russia's Developed an EMP Weapon Against a Drone Swarm. So Russia has developed your idea and I'm not sure if the United States has something equivalent. But I certainly hope so. Because this is chilling stuff.

Robert J. Marks:

Again, the drone swarm, I think the autonomous unmanned drone swarm is one of the most chilling applications of artificial intelligence and warfare. Cause it's going to be very hard to defend against, I read one military expert that says they can expect up to, I think this might be a little bit of hyperbole, but he said up to a million elements in a drone swarm, which is astonishing-

Sarah Seguin:

Really?

Robert J. Marks:

Yes. Yes.

Sarah Seguin:

That is astonishing.

Robert J. Marks:

And how do you do them? You can't do them one at a time. You can't do a defensive one-on-one dog fight with all of the elements in the swarm. So the EMP sounds like a great solution. It's like having a bug spray, you can go step on the ants one at a time, and that takes forever. Or you could go spray the anthill with some insect killer and kill them all at once. That's what the EMP would do.

Robert J. Marks:

And that would be astonishing. I was really impressed with that solution. Cause autonomous drone swarms have been worrying me for quite some time. So.

Sarah Seguin:

Well, and this is all in the open literature articles you can search. Raytheon has actually developed directed energy weapons. One of the most famous ones that's easy to Google is they have a crowd control weapon, which I don't believe was ever actually implemented as a crowd control weapon, but it was developed.

Robert J. Marks:

Okay. You got to tell me, how do we do crowd control with an EMP device? What would be the effect?

Sarah Seguin:

It's not using an EMP. What it's using is directed energy that's at a frequency that actually causes to feel like your skin is itching.

Robert J. Marks:

Really?

Sarah Seguin:

Yeah.

Robert J. Marks:

Oh my gosh. I got to find out the frequency for that. That would be a fun trick to play on your colleagues.

Sarah Seguin:

So all great technology like microwaves. I'm sure it was discovered by accident, right?

Robert J. Marks:

Yeah.

Sarah Seguin:

Maybe not. I don't know. I can't remember the frequency, I apologize. But yes, they have a directed energy crowd control weapon, if you will. But I don't think it's actually been implemented at least in the US. But I did find some articles that talked about how the military is pushing various contractors to do more directed energy weapons. So I sincerely hope that they are working on it as well. And it's just really quiet and it just got out with Russia.

Robert J. Marks:

Yeah. A lot of this development I'm sure is classified. So hopefully the United States with all of the accelerated emphasis on the military infrastructure, is looking at this. And I know both you and I, Sarah work with research officers on classified material from the army in the Navy. And I tell you, working with these people is just wonderful. We do no classified work currently. But these people are very focused on getting tools to the American war fighter and are very impressive people.

Sarah Seguin:

Yeah. We have some really brilliant researchers and technologists working in the United States to develop great tools.

Robert J. Marks:

We do. And they just need to be set free and they are going to develop great countermeasures to some of these chilling weapons. Well, thank you, Sarah. That was been a fascinating chat. Our guest today has been Dr. Sarah Seguin, an electrical engineer who specializes in electromagnetic compatibility and in the area of EMPs. So until next time be of good chair.

Announcer:

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