On the Electromagnetic Shielding Effectiveness of Chain-Mail Armor

Stefano Selleri

Department of Information Engineering
University of Florence
Florence, Italy
E-mail: Stefano.selleri@unifi.it

Chain-mail armor was a type of body protection that dates back to the fourth century BC. It was used extensively in times of war up to the advent of firearms. It had a limited use later on, but was still reported as being worn up to the 20th century.

The modern uses of chain mail are mostly civilian, such as protection for butchers, shark protection for divers, and, notably, for historical reenactment and live-action role-playing games. In these latter cases, there is no need that the chain mail really be weapon proof, and it is usually made of aluminum to reduce weight.

It is legitimate to ask ourselves if chain mail could be used as a wearable shield against electromagnetic radiation.

1. Electromagnetic Analysis Approach

Chain mail (Figure 1) is composed of interlocking rings. In the most common form, these are woven so that each ring is connected with four others (Figure 2). The rings are, of course, opened to allow weaving. They may be soldered or riveted for superior strength, or they may just have their ends juxtaposed.

The rings are usually quite small, usually between 3/8 in to 1/2 in (9.5 mm to 1.3 mm) diameter. This makes creating chain mail a long and tedious task, yet this also makes a planar chain-mail sheet a periodic surface. Under the

Figure 1a. The chain-mail armor and equipment of a Polish medium cavalryman, from the second half of the 17th century [Wikipedia, photo by Dariusz T. Wielec, Free Art License 1.3].

Figure 1b. A modern chain-mail coif [Wikimedia commons, photo by Immanuel Giel, public domain].

Figure 2. Modern chain mail. The four-in-one weaving pattern is apparent [Wikimedia Commons, photo by Matthias Kabel, Creative Commons Attribution-Share Alike 3.0 Unported license].

realistic hypothesis that such a sheet of mail is illuminated by an electromagnetic source far enough away in space so that the electromagnetic field can be assumed to have a plane-wave structure, the problem can be analyzed on a single periodic cell with appropriate periodicity boundary conditions (Figure 3 and [1]).

A simplified electromagnetic model is sketched in Figure 3. For completeness, two models were considered. The first was an "isolated" model, in which no electrical connection was present between rings, hence effectively simulating passivated or painted surfaces, allowing for capacitive coupling but not for current flow. The second was a "connected" model, in which the rings were touching, hence simulating electrical connection between rings and hence the possibility of current flow among them. In both cases, the rings were modeled as a toroid with a radius of revolution of 6 mm (0.23622 in) and a revolving section that was a circle. For the "isolated" case, the radius of the revolving section was 0.75 mm (29.52 mils), while for the "connected" case, the radius was 1 mm (39.37 mils) (Figure 3).

2. Numerical Results

The problem was hence reduced to that of a periodic cell illuminated by a plane wave, and was numerically solved. The results were given in terms of the transmitted intensity ratio and the reflected intensity ratio, in dB, for both connected and unconnected rings, over a 100 MHz to 10 GHz band (Figure 4). In the figure, the band from 300 MHz to 6000 MHz is highlighted, since it holds most mobile phone standards up to 3G and 4G, going up from 300 MHz to 2600 MHz [2, 3], as well as Wi-Fi, which, as described in IEEE Standard 802.11, covers the 2.4 GHz to 5.9 GHz band [4].

It was apparent from Figure 5 that for the lower part of the spectrum, the chain mail guaranteed at least 20 dB attenuation in the transmission up to 3 GHz, and that the connected mail gave about an extra 5 dB of protection. This was expected, since in the connected mail, current paths could freely cross rings, and not only through parasitic capacitances. In any case, resonances in the mail arose where the ring circumference (about 2 cm) started to be comparable with a wavelength. Indeed, resonances appeared at lower frequencies with respect to a single isolated ring, due to the reactive load of the neighboring rings, causing a significant reduction of shielding effectiveness at the top of the Wi-Fi band.

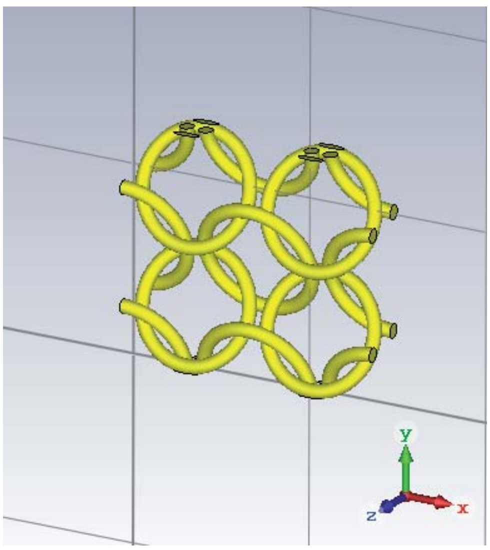

Figure 3a. The isolated-rings model

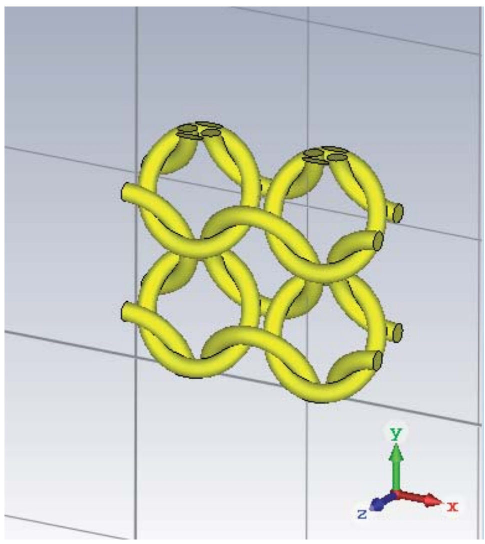

Figure 3b. The connected-rings model.

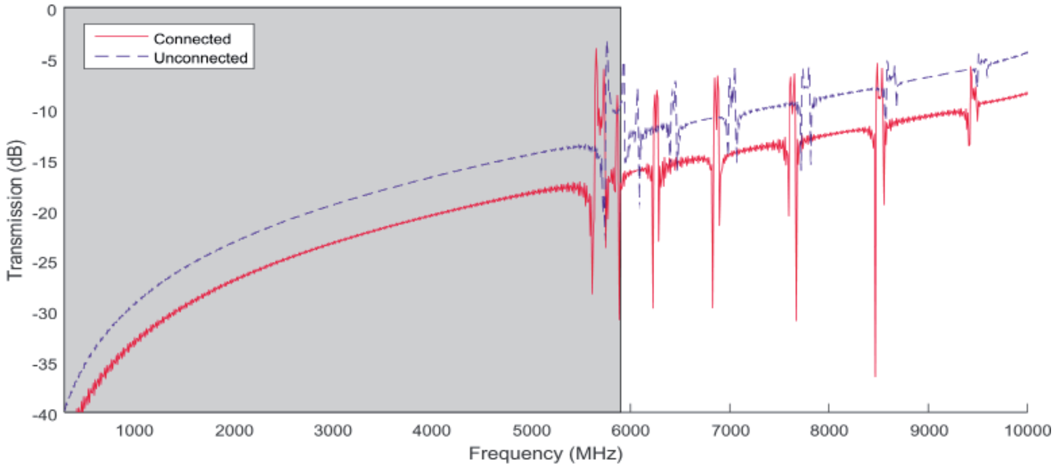

Figure 4. The transmission through the connected (solid line) and unconnected (dashed line) chain mail.

The shielding level (a few tens of dB) was much lower than that of a solid aluminum shield, the effectiveness of which may exceed 100 dB at these frequencies. A solid aluminum or other metal shielding can be provided by full-plate mail, which, unfortunately, is much less comfortable to wear.

3. Clinical Data

Although for ethical reasons it was inappropriate to have volunteers walk around in full chain mail all day long while using their mobile phones or surfing the Internet via Wi-Fi, some indirect proof of beneficial effects on health could be inferred from statistical data on mortality collected when chain mail was fashionable.

By browsing historical references, we have evidence of a large number of deaths during the Crusades (1095-1291) among people wearing various kinds of armor, typically chain mail [5]. However, deaths other than due to old age were credited to pestilences, battle, injuries, or starvation. The author could not find in the records a single case reporting brain cancer, or any other cancer, for that matter [6].

4. Conclusions

Wearing chain mail significantly lowers electromagnetic radiation absorbed by your brain or body. It is anyway advisable to keep the phone outside the coif when talking. Otherwise, radiation would occur within the shield, which would act as a low-*Q*-factor resonant cavity. That would enhance rather than diminish the effects of the radiation.

5. References

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