Dangers of Electro-Magnetic Fields

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Over earlier years we have carried on sending radio signals around the surface of the earth at a wide range of frequencies and at some quite high powers, with not too much of concern whether electro-Magnetic Fields could be harmful. In more recent times, the concern has grown and a lot of people are worried about it. But there are a lot of variables involved in deciding what is harmful to the human body. I thought I would have a look at what could be made of all this.

Foreword

The article commences with the elements of matter, how they form fields in a tuned antenna and the characteristics of those fields. Fields are examined from broadcast stations, mobile phones (including the potential danger to the human brain), and danger to amateur radio operators. There is also a discussion on field strength measurement and body heat build up from fields. One might be surprised at what I have said about the formation of Electro-Magnetic Waves.

Theory on the formation of Electro- Magnetic Fields

In defining the structure of matter we have elements called Electrical Conductors and elements called Electrical Non Conductors or Insulators. There are also some elements which have both characteristics and are called Semi-Conductors.

A Conductor can pass electrical current which flows into it and it stores energy and creates a magnetic field. From this, the current creates a magnetic field. The component is called an inductor. .

At the ends of the inductor, two plates may be formed. With an insulator between them, an electric potential is developed across the plates and these create an electric field. The component formed is called a capacitor and this also stores energy.

The process results in separate fields being generated, one from the current running in the circuit and the other from the voltage developed across it. The current and voltage are 90 degrees out of phase with each other and no energy is generated by these components in their own right.

But Energy is generated when there is resistance in series with the looped circuit. Energy can also be coupled from an external field through the inductor. And an electric field can couple in energy across the plates of the capacitor.

When the inductor and a capacitor are connected together, they form a tuned circuit which if excited from an external magnetic or electric field, it can be triggered into self oscillation called resonance. The self oscillation will occur at a frequency determined by the characteristics of the elements. The resistance in the circuit represents power loss in the circuit in the form of heat.

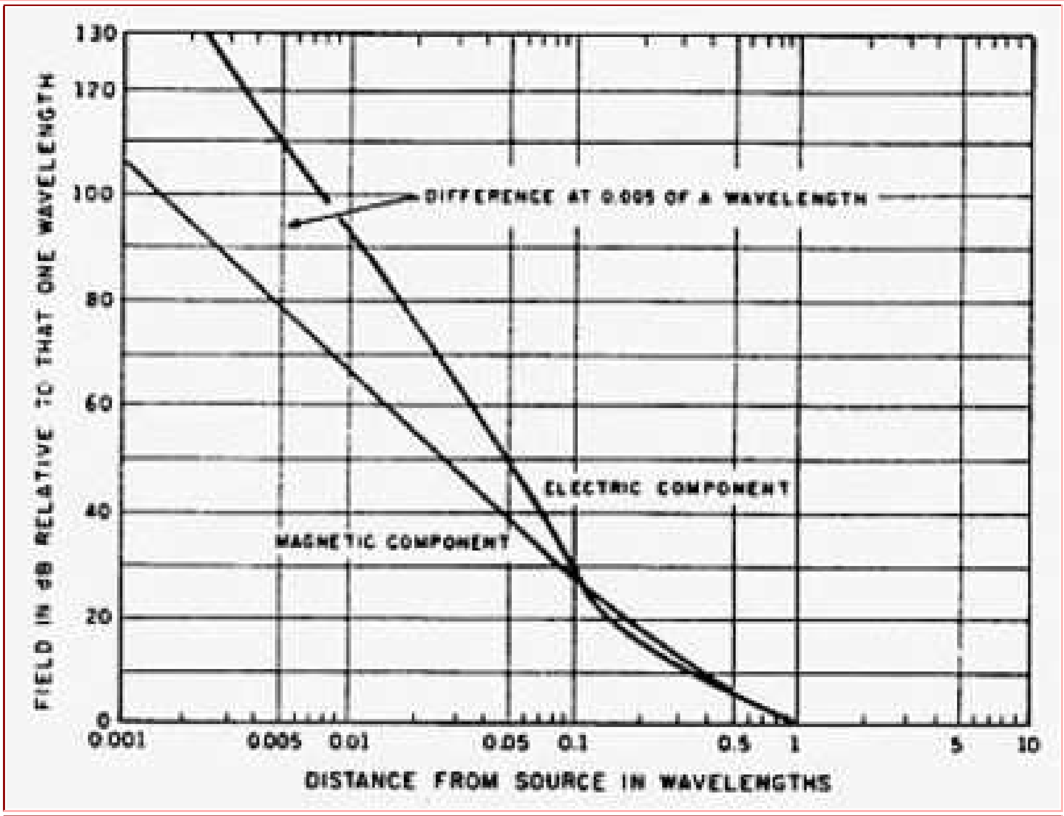
At resonance, energy is stored by the capacitor during part of the oscillating cycle and also returned to the circuit during further parts of the cycle. The ratio of power circulated to power lost is what we call Q factor. If that factor is high, we get high voltage developed across the paralleled capacitor and we get high current through the series loop, including the inductor.

The combined magnetic and electric fields from the resonance make up what has been called an electro-magnetic wave. In the form of a half wavelength tuned antenna, the fields are very strong within the first half wave distance from the antenna electrical centre. This part of the field is often called the Near Field. The following algarithums and curves have been prepared from an early text book to demonstrate the high field strength in that first half wave..

1. The electric component of the induction field decreases with the cube of the distance and dB = 601og (d2/d1) where d2 and d1 are the relative distances.

2. The magnetic component of the induction field decreases with the square of the distance and dB = 40log(d2/d1)

The vector sum of the combined electric and magnetic components decrease directly with distance and dB = 20log (d2/d1). In the abscence of loss In the transmission path (if this could occur), the curve, if put in the following diagram, would just sit on the X axis as zero field strength.



The Near Electromagnetic Fields showing their Exponential Expansion of Amplitude verses Distance from the Antenna Centre

The effect of all this is that, in the near field, the electric and magnetic components continue from the antenna electrical centre for a radial length of about half a wavelength, falling to a signal level where their combined strengths form near a linear slope at the half wave point. In the near field, these two field components are clearly much stronger than beyond the half wavelength.

The fields continue on their way , decreasing in amplitude and in reverse exponential form, continuing towards infinity.

Being 90 degrees out of phase with each other, when the amplitudes are added as vectors, the resultant is also a sine wave plot of shape giving the appearance of a third field. Text books have listed this as a third field and called it an electromagnetic wave, but it isn't really another field. It is the vector sum of the two individual fields (Perhaps we could call it a ghost field). In terms of time, the ghost field is phased somewhere between that of the two individual fields. I think that if the fields were of equal amplitude, the ghost field would be at 45 degrees to the others. The important conclusion is that there is no third radiation field. The amplitude of the vector addition can be detected and displayed as a sine wave on a CRO but the energy carried is shared between the two fields (electric and magnetic).

<u>Field Strength of Broadcast Stations</u>

But all this leads us further into the fields of powerful MF broadcast stations and and others in the LF/MF region, such as the Homer Beacons (NDB's). Some of these stations run quite high power. Several of the national broadcast stations stations run 50kw and 100 kw. The Near Field components of these LF/MF stations would extend up to1.25 km from the station transmitting antennas for the longest wavelength.

MF Broadcast stations in the past have been required by legistration to be consistently staffed by qualified operator/technicians when the stations are on the air. This has put the operators in the position of possible health effects from the continuing radiated fields over the operational work 'shift'.

In the city of Adelaide, broadcast transmitters and their towers have been operated in large building complexes. Workers in those buildings and also the buildings around them, would have been affected by the near fields.

These stations in the city have been limited to 500 watts of output power. As time progressed, higher power stations have been relocated to more isolated locations where there is low density housing. Some of these higher power stations were initially also manned, but ultimately they were remote controlled and only needed occasional visits from the technical staff. Hopefully their visits were limited in time. (See section on "Dangers in Lapsed Time of Fields")

Dangers to transmitter staff is one thing but there is also the problem of residents living too close to broadcast transmitters and other transmitting stations, A serious example in South Australia is the national broadcast station at Pimpala, Reynella SA. First established in1959 amid open fields, there was hardly a residence in site from the station which generated 100 kW plus of power. Clearly the station was established by the PMG managers to get away from residental housing. This was fine for many years, but the housing developers finally caught up with the clear land and now there are houses just across the road from the transmitter installation.

Damage to the Brain and Mobile Phones

I have given thought to possible damage to the brain from electro-magnetic fields. This is based on resonance in the brain area and being triggered by microwave radio signals from closeness of the Mobile Phone. Judging from the dimensions of the brain assembly, resonant frequency would be in the microwave region. But resonance might also be triggered from lower frequency fields from MF transmitters, which have been discussed. But how can the lower frequency of typical broadcast stations, or the homer beacons, excite resonance at microwave frequencies.?

To give some suggestions on this, we can go back to microwave frequency theory where they use various types of oscillators such as the laser and where a microwave oscillator is pumped by a lower frequency. Or there is the simple semi-conductor diode which on rectification generates copious harmonics. No doubt the brain is made up of basic elements, pure conductors, insulators, and semiconductors. So maybe the brain can rectify the incoming sine wave signal to produce a harmonic which will pump a resonance in the brain.

Getting back to the mobile phone, the phone is normally operated close to the ear, which when transmitting, induces an induction field into the head. The induction field is extremely strong and distance between the mobile phone and the brain is within the half wave near field area. For Australian mobile channels, the strong near field is between about 8cm (for 5G) and about 30 cm for the lowest frequency channel. All the mobile channels are within the length of the strong near field region, the lowest field strength being at the 5G end.

I do believe that triggered resonance in the brain is a danger from an incoming signal or a mobile phone held to the head. I am suggesting that if the brain has a resonance at the incoming signal frequency (or harmonic of it), it might cause a lot of heating in that area. If that heating is excess in the brain, it might respond with some form of pain, perhaps a headache (or something more serious). (Refer also to the section "Dangers in Lapsed Time of Fields").

I believe there are few limits which have been considered for field strength and a lot of testing has been done by telephone companies. But their testing seems to be field tests triggered by public fear of repeaters on towers. I think that if there is a worry, it is the close proximity of the mobile phone to the brain, right in the near field of the phone transmission, rather than the field of the towers themselves, which are beamed well above the ground.

Danger to the Radio Amateur

The question of amateur radio transmission is now considered with discussion on how the amateur operator might be affected by strong fields. Looking at the attached field strength curves, field strengths above the 0.1 wavelength point, is the strong near field which is examined.

Danger to the Amateur Operator from his own transmitter obviously depends on the frequency of transmission, the average radiated power, the distance between the operating location and the antenna and a few other variables.. All this may be undefined, but I have nominated 8 metres between the antenna centre and the operating location and and consider whether the Near Field lays along this line. It is not all the answers to safety but it is somewhere to start.

The 160 metre band is the most probable one to cause high induction levels from the Near Field. The radio amateur usually operates with the usual 160 metre antenna above the house. On 160 metres, the Near Field extends to 16 metres and certainly floods the 8 metres distance with a high field strength level. On the 80 metre band, the Near Field ends at the 0.1 metre point, so that the band field strength extends downward below the 0.1 wavelength point, If the operator sat a little more than 8 metres, the person would probably be quite safe.

For wavelengths shorter than the 80 metres, the operator should feel quite safe with 8 meters distance to the antenna exceeded. But there is one provision, if the antenna is a directional beam, don't point it towards the operating point.

In using the increased wavelengths of the LF/MF bands, one should be very careful. The 630 metre Band has a Near Field radius from a probable non directional antenna of 315 metres.

For 2200 metres, to predict the danger from an antenna the amateur operator might be able to built for this band, it is not too clear. One might not be able to achieve much radiation efficiency, and not provide much field strength to cause danger. The practical amateur antenna, would probably be electrically very short, a fraction of an ohm, and the loss resistance in the earthing or counterpoise, much larger than the radiation resistance.

On the other hand, there would be a strong ground current running in the earth below the operator and creating a field above the ground. If one can walk aound the radio shack with a fluoru lamp lighting up in the hand, the field strength is high and dangerous.

Field Strength Testing

The most practical thing to do in protecting against body damage from excess field strength is to make use of a calibrated Field Strength meter. I down-loaded a copy of "Australian Standard on Radio Frequency Fields Exposure Level" and this indeed is a complex document. It has a multitude of variable factors, making it difficult to come up with a general algorithm which can define a general Field Strength level. And of course, this is a level which is considered reasonably safe for those who have need to operate or work within Radio Electro-magnetic Fields.

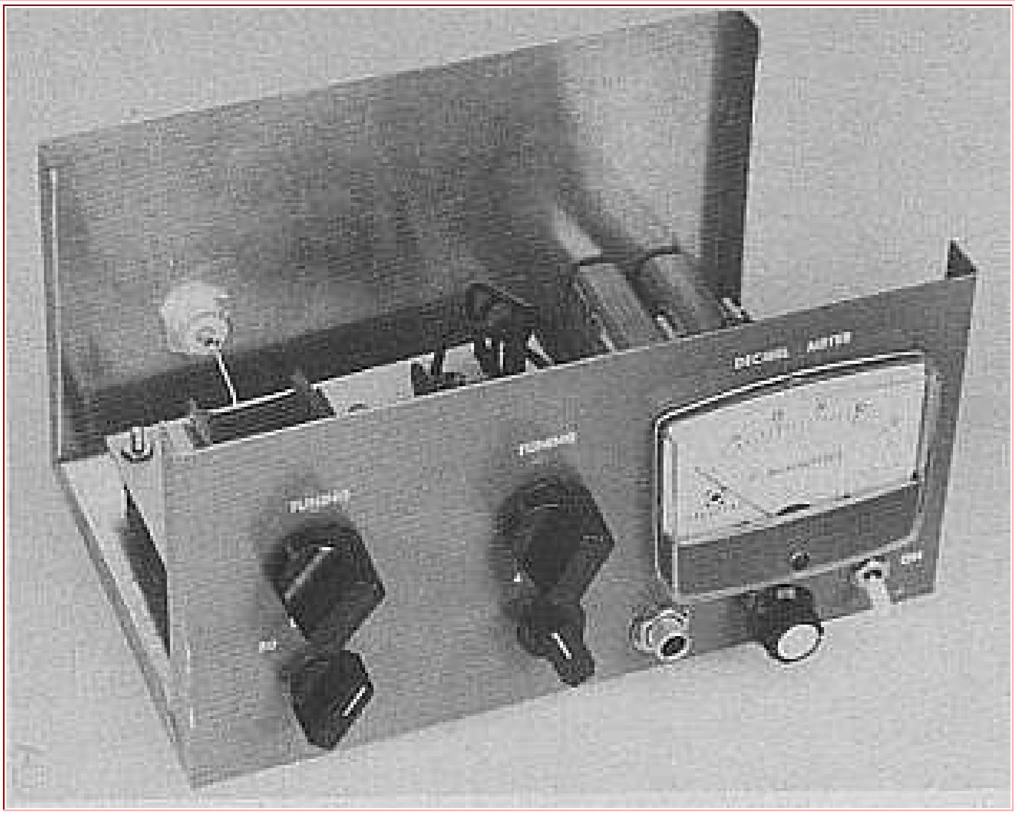
From what sense I could make of the documentation, there is a safety standard for limitation of field strength as follows: Maximum Field Strength = 40TmV/metre. The character T, standing for Tesla, is a constant defining several of the variables related to the fields. (I can't say that I am confident that the formular I derived is right - If someone has some different information, by all means contact me.).

From another source, I found maximum field strength power P is equal to E (200 mV} squared divided by R (R, space impedance = 376.7 ohms). This led to a field strength of 27.5 mV/metre. (And of course I am not all that confident in the formular of this either).

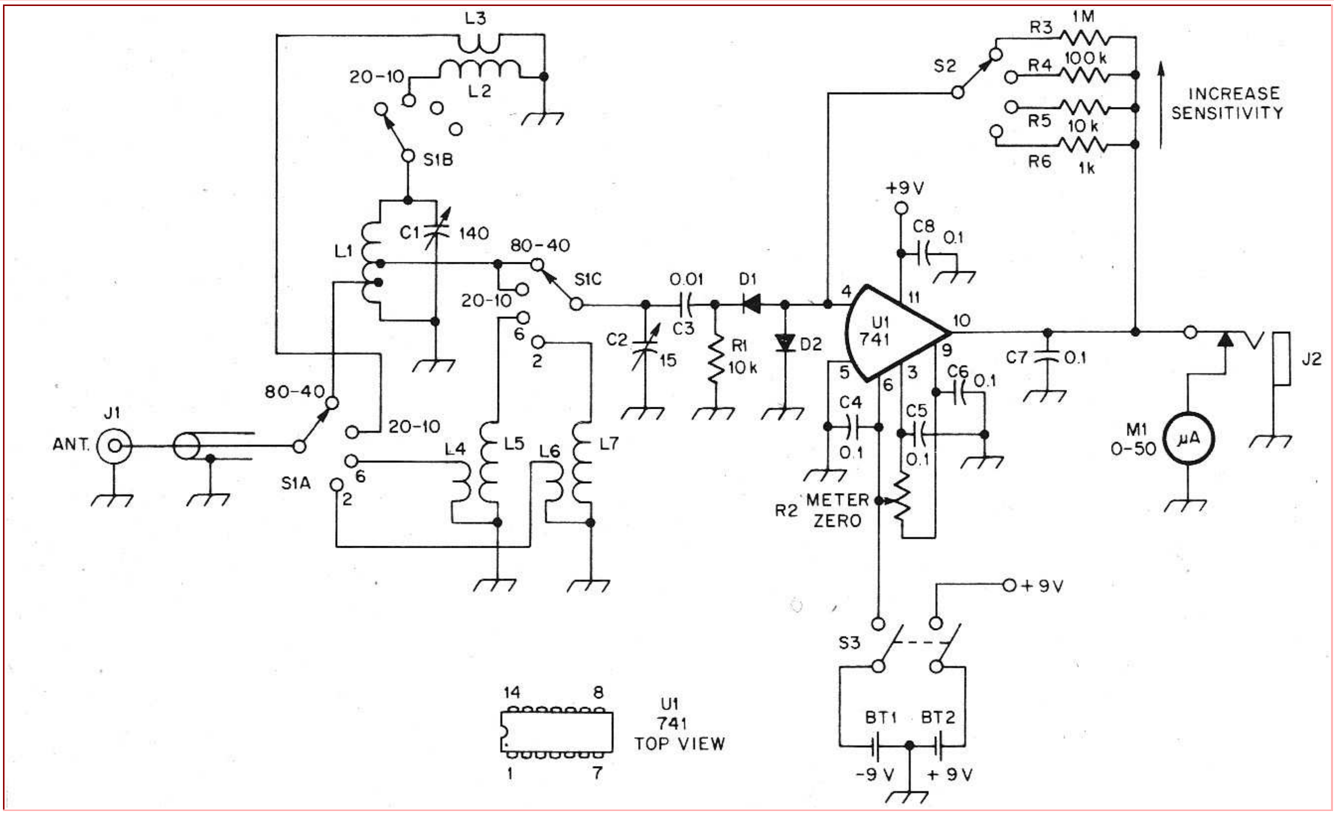
But on to some practical amateur radio construction. The following picture and circuit diagram are a field strength meter taken from an ARRL Handbook. The ARRL model uses a plug in antenna for each band. A diagram is also shown illustrating the structure of the loop antenna for 28 Mhz. I note the absence of a comparison of sensitivity between the different frequency antennas. The illustrations and the reference below, could be a guide for home construction. I think it would be a good idea for someone who enjoys taking on this type of project to build a prototype that others could copy and reproduce.

It is the type of project which radio clubs sometimes set up to distribute models to their members. I am thinking of someone who might take this on and in the process perhaps even come up with a simpler circuit.

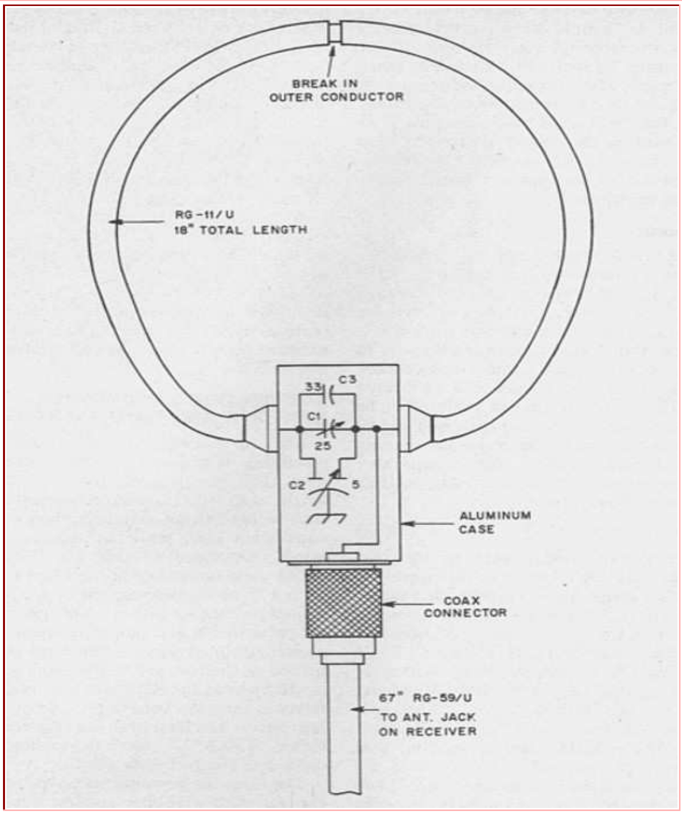
Of course to be put into use, each instrument constructed must be calibrated against another trusted meter. Note also that in the ARRL design, the different band antennas don't appear to be compared for their signal sensitivity. Once a prototype is constructed and calibrated, copies of the unit can be made. Copies should work the same if the components are identical to those of the propotype



Field Strength Meter Picture (ARRL Handbook)



Field Strength Meter Circuit (ARRL Handbook)



Loop 28 Mhz
Field Strength Meter (ARRL Handbook)

Time Exposure to Electro-Magnetic Fields

A final factor concerning limits of exposure to fields is the time exposed. Heat temperature builds up and can cause some damage. Heat energy is absorbed by the body (or parts of it), but energy is also transmitted from the body. The temperature keeps rising until the heat entering the body balances the energy being transmitted. If that point is beyond the Field Strength time Limits, look out for a threat to your health.

Rays from the sun are also electro-magnetic fields. In getting a sample of sunbaking, I observed the following: After exposure to the sun for 10 minutes, I noted that the section of the my body exposed was getting tolerably warm. I came to the conclusion that this was a warning that if I persisted any longer, I might get sun-burn . So I took a break!

Along these lines, when testing your radio field strengths, you might be able to use a similar idea wih the radio electro-magnetic fields. If some part of the body is feeling warm, give the transmitted signal a break for a while. Perhaps you could try 10 minutes or a bit longer.

I think I need to say a few words about mobile phones and their owners. In particular those owners who live with their Smart Phones all day, spending hours of continuous time using them without a break, and including those who down-load long files such as DVDs. Again I suggest, breakup transmission into short lengths of time.

Summary

The article is all about Electro-Magnetic Fields and possible danger from them. I have introduced the article with some theory on the fields and in particular those in the Near Field region. We move on to the fields transmitted by MF broadcast stations and other stations in the LF/MF region, On to possible damage to the brain by mobile phones, and then to how the Radio Amateur fares with the fields generated by the personal amateur radio station.

There is a section on Field strength testing with a test instrument illustrated which you might consider building or suggesting to your Radio Club as a project.

And finally a little about spending too much time transmitting (perhaps radio net 'Overs'), or too much time listening to MF broadcast transmitters or other types of of transmitting sources.

As you might gather, the information I have researched to assemble the article, does not lead to highly acurate mathematical safety limit figures. My main theme has been to point out when the strong near fields appear threatening.

But hopefully what I have written is a lead in that direction, to improve the safety of those, who engage in work or pleasure in the presence of those electro-magnetic fields.

References

(1) ARRL Handbook - 1989 edition, pages 39-10 to 39-16.

(2) Report - Australian Standard on Radio Frequency Fields Exposure Level