Mathematica code for Implementing the aggregate EMF

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April 15, 2020

Abstract

This report contains the Mathematica code, used to implement the aggregate EMF spectral density due to several nearby transmitters.

1 Introduction

Currently power constraints are expressed as if devices share spectrum by never using the same frequency at the same time as a nearby device. However, efficient use of spectrum over time forces wireless protocols to use the same spectrum at the same time as nearby devices [1]. Under these circumstances, if many users cluster together, the health impact of their wireless communication will be cumulative. The total EMF spectral density (Electro-magnetic field spectral density, in $V/m/Hz$), of all nearby devices, is what needs to be regulated, for the health of those in the vicinity of these devices, which has been implemented in Mathematica, and the scripts code for it are included in this report.

2 Description of Code

This report has three Mathematica files; firstly, Listing 1 in the system descriptions the main program of aggregate EMF spectral density. Secondly, Listing 2 shows the aggregate EMF due to several nearby transmitters, assuming each transmitter limits its own power independently, without concern for ambient EMF, is plotted in Figure 1. This figure shows a typical situation of several devices inside the

1

same building or vehicle which are using the same spectrum. Each device transmits at the same time. The EMF intensity is higher than that of a single transmitter because it is the aggregate effect of all the transmitting devices.

Finally, the Mathematica file Listing 3 displays the resulting aggregate EMF, with the same configuration of devices as previously, all these devices sense and measure the EMF in the region where they are active, is shown in Figure 2. In this case, the regulated limit on aggregate EMF is respected. This approach is therefore safer.
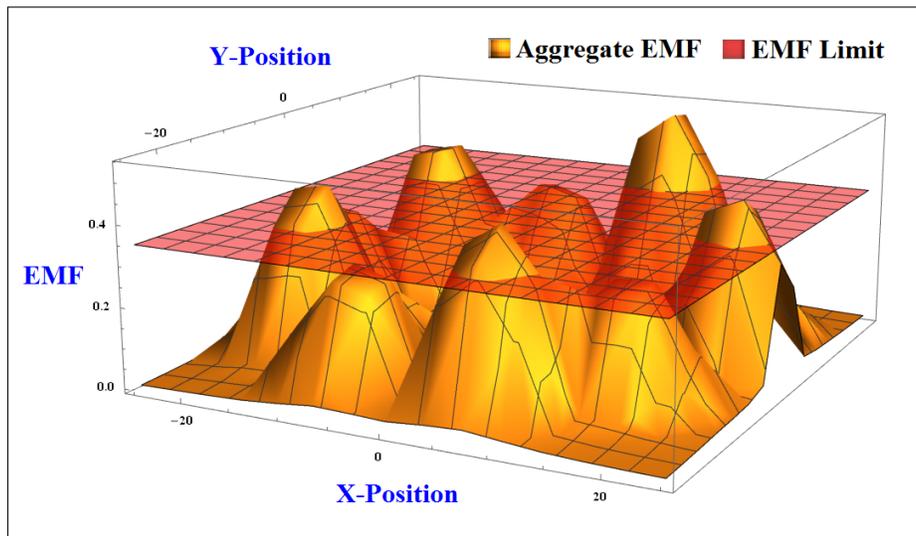
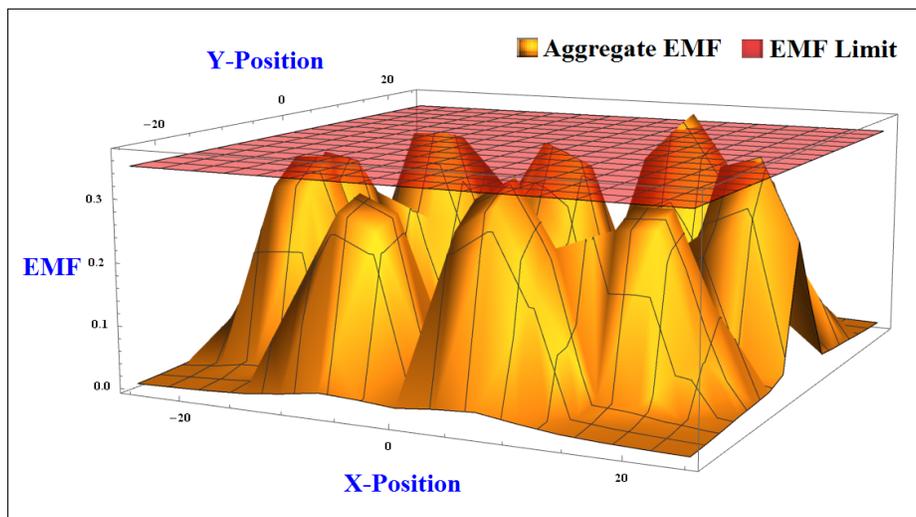Figure 1: The aggregate EMF due to several nearby transmitters

Figure 2: The aggregate EMF when devices measure ambient EMF and limit the total

Aggregate Field Strength
****

Parameters
~~~~~~~~~~~

The parameters of the location of transmitters, and their transmission characteristics are defined here. We can use systematic, random, or arbitrary locations (specify each one explicitly). The first choice we have here is systematica -- a grid.

Location Parameters
****

Grid
~~~~

```
hseparation = 5; vseparation = 5; hnum = 5; vnum = 5;
locations = Flatten[Table[
    Table[{j hseparation, k vseparation},
      {j, 0, hnum - 1}], {k, 0, vnum - 1}], 1]
```

```
{{0, 0}, {5, 0}, {10, 0}, {15, 0}, {20, 0}, {0, 5},
 {5, 5}, {10, 5},{15, 5}, {20, 5}, {0, 10}, {5, 10},
 {10, 10}, {15, 10}, {20, 10},{0, 15}, {5, 15},
 {10, 15}, {15, 15}, {20, 15}, {0, 20}, {5, 20},
 {10, 20}, {15, 20}, {20, 20}}
```

```
{{0, 0}, {5, 0}, {10, 0}, {15, 0}, {20, 0}, {0, 5},
 {5, 5}, {10, 5}, {15, 5}, {20, 5}, {0, 10}, {5, 10},
 {10, 10}, {15, 10}, {20, 10}, {0, 15}, {5, 15},
 {10, 15}, {15, 15}, {20, 15}, {0, 20}, {5, 20},
 {10, 20}, {15, 20}, {20, 20}}
```

```
locations[[1]]
```

```
{0, 0}
```

Circle
~~~~~~

```
nloc = 10; radius = 20; locations1 :=
 Table[{radius Cos[k 2 Pi /nloc],
    radius Sin[k 2 Pi /nloc]},
   {k, 0, nloc - 1}];
N[locations1]

{{20., 0.}, {16.1803, 11.7557}, {6.18034, 19.0211},
 {-6.18034, 19.0211}, {-16.1803, 11.7557}, {-20.,
   0.}, {-16.1803, -11.7557}, {-6.18034, -19.0211},
 {6.18034, -19.0211}, {16.1803, -11.7557}}

xoffset = 1; yoffset = 1.5; nloc2 = 5; radius = 20;
locations2 := Table[{radius Cos[k 2 Pi /nloc2] + xoffset,
    radius Sin[k 2 Pi /nloc2] + yoffset},
   {k, 0, nloc2 - 1}];
N[locations2]

{{21., 1.5}, {7.18034, 20.5211}, {-15.1803,
   13.2557}, {-15.1803, -10.2557}, {7.18034, -17.5211}}

locations := Union[locations1, locations2,
   {{6.22, 18.75}}];
N[locations]

{{-20., 0.}, {6.22, 18.75}, {20., 0.},
{21., 1.5}, {-16.1803, -11.7557},
{-16.1803, 11.7557}, {-6.18034, -19.0211},
{-6.18034, 19.0211}, {6.18034, -19.0211},
{6.18034, 19.0211}, {16.1803, -11.7557},
{16.1803, 11.7557}, {-15.1803, -10.2557},
{-15.1803, 13.2557}, {7.18034, -17.5211},
{7.18034, 20.5211}}


ourorder = {1, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 14,
            15, 16, 2, 10};
locationswithextra := Table[locations[[ourorder[[k]]]],
                      {k, 1, 16}];
```

```
N[locationswithextra]

{{-20., 0.}, {20., 0.}, {21., 1.5}, {-16.1803, -11.7557},
 {-16.1803, 11.7557}, {-6.18034, -19.0211},
 {-6.18034, 19.0211}, {6.18034, -19.0211},
 {16.1803, -11.7557}, {16.1803, 11.7557},
 {-15.1803, -10.2557}, {-15.1803, 13.2557},
 {7.18034, -17.5211}, {7.18034, 20.5211},
 {6.22, 18.75}, {6.18034, 19.0211}}

Length[locationswithextra]

16

Random

Transmission Parameters
~~~~~~~~~~~~~~~~~~~~~~~~~~

gamma = 2 (* Distance decay exponent *);

nearfieldthresh = 6;
```

Listing 1: The main program of aggregate EMF spectral density

```
Aggregate EMF
*************:

1) Aggregate EMF with no Measurement of Ambient EMF
***************************************************

Length[locations];
margin = 5

emf[r_] :=
  Which[r > nearfieldthresh, r^- gamma,
   r <= nearfieldthresh,
   nearfieldthresh^-gamma +
    0.05 Sqrt[nearfieldthresh^2 - r^2]];
SourceEMF[x_, y_] := Module[{r = (Sqrt[(x[[1]]
```

6

```
            - y[[1]])^2 + (x[[2]] - y[[2]])^2)},
  emf[r]]

Plot3D[SourceEMF[{u, v}, {5, 5}],
 {u, - margin hseparation,
  (1 + margin) hseparation},
 {v, - margin vseparation,
  (1 + margin) vseparation},
 PlotRange -> Full]


EMFLimit[x_] := 0.35;
AggEMF[x_] :=
 Sqrt[Sum[SourceEMF[x, locationswithextra[[k]]]^2, {k ,
    Length[locationswithextra]}]];
    hleft = -radius - margin;
    hright = radius + margin;
    vleft = -radius - margin;
    vright = radius + margin;


Plot3D[{AggEMF[{u, v}], EMFLimit[{u, v}]},
 {u, hleft, hright}, {v, vleft, vright},
 PlotStyle -> {, {Opacity[0.5], Red}},
 PlotLegends -> Placed[
   {"Aggregate EMF", "EMF Limit"},
   {Right, Above}], AxesLabel -> {Style
   ["X-Position", 25, Bold, Blue],
   Style["Y-Position", 25, Bold, Blue],
   Style["EMF", 25, Bold, Blue]},
 LabelStyle -> Directive[15, Black, Bold,
   FontFamily -> "Times New Roman"],
 MaxRecursion -> 15]
```

Listing 2: Aggregate EMF with no measurement of ambient EMF

```
2) Aggregate EMF with Measurement of Ambient EMF
************************************************

AggEMFFromOthers[x_, self_] :=
  Sqrt[Sum[SourceEMF[x, locationswithextra[[k]]]^2,
    {k , Table[kk, {kk, 1, self - 1}]}]];
AggEMFWithAmbientMsmnt[x_] :=
  Sqrt[Sum[(((SourceEMF[locationswithextra[[k]],
          locationswithextra[[k]]])/
        (AggEMFFromOthers[locationswithextra[[k]], k] +
          SourceEMF[locationswithextra[[k]],
           locationswithextra[[k]]]))
      SourceEMF[x, locationswithextra[[k]]])^2,
    {k , Length[locationswithextra]}]];

Plot3D[{AggEMFWithAmbientMsmnt[{u, v}],
  EMFLimit[{u, v}]}, {u, hleft, hright},
 {v, vleft, vright}, PlotStyle ->
  {, {Opacity[0.5], Red}}, PlotLegends ->
  Placed[{"Aggregate EMF", "EMF Limit"},
   {Right, Above}], AxesLabel ->
  {Style["X-Position", 25, Bold, Blue],
   Style["Y-Position", 25, Bold, Blue],
   Style["EMF", 25, Bold, Blue]},
 LabelStyle -> Directive[15, Black,
   Bold, FontFamily -> "Times New Roman"],
 MaxRecursion -> 15]
```

Listing 3: Aggregate EMF with measurement of ambient EMF

3   Conclusion

The aggregate EMF due to several nearby transmitters, assuming each transmitter with no measurement, and with measurement of ambient EMF, have been implemented and tested. All the code for this system is included in this report.

References

[1] IEEE Standards Association and others. 802.11-2012-IEEE standard for information technology–telecommunications and information exchange between systems local and metropolitan area networks–specific requirements part 11: Wireless lan medium access control (MAC) and physical layer (PHY) specifications. *Retrived from http://standards. ieee. org/about/get/802/802.11. html*, 2012.