Wireless Luminaires

Designing Luminaires for Wireless Performance

Everything goes wireless, also luminaires, mostly using mesh-kind of RF communication for control. There are all kinds of off-the-shelf RF electronics available for the Luminaire Designer.

This leaves the Luminaire Designer with a big question mark: "How to design a luminaire for reliable RF communications in the field."

Luminaire Designers Nightmare

The ultimate nightmare for the Luminaire Designer is a real estate project at the other side of the world, with thousands of luminaires, all mounted high at the ceiling... Where some 5% of them do not work every now and then.

You do not want to go around repositioning the (fixed) luminaires for getting good results. And most likely the units will have been installed by an other company, by people you do not know and in premisses of which you cannot get the details. A company that will not be pleased with the performance and you'll never know for sure whether or not the installation instructions have all been properly followed.

Predicting Wireless Performance

Let's be honest: "Wireless Real Life" is far too complicated to model it in a simple way, if modelling it in any reliable way is possible at all!

This not only applies to installing the luminaires in a building. **It all starts with the design of the luminaire itself for RF-performance, given a certain RF-module!**

Giving design rules and measurable limits for a set of parameters to insure e.g. 99,5% reliability in the field, is impossible without (expensive) over-specification.

A good RF-designer is worth it's weight in gold, because he or she has acquainted him/herself with many of the unpredictable influences surroundings have on wireless communications.
But there are very few of them around, RF is not a very popular specialisation, it is not very easy to learn and takes years.

That's the reason that you'll find so much sense and nonsense around RF. Some is pure lore, other is based upon observations that are valid for one specific case only.

"So what's the Problem...?"

Let's get more specific about the problems the Luminaire Designer faces: He or she has a lot of knowledge of lighting, mechanics, fabrication technology, industrial design and lifestyles, colour schemes, safety standards, etc.

Yesterday´s electronics that were integrated in the luminare's design were often plug and play because it used wired networks. A lot of work to install the luminaires in the building, but when done correctly, it simply works. And if not, the unit was defective.

With the coming of RF this all changes. You can have a perfectly working RF-module, *and* having no/communication at the same time in the field.

Price and aesthetics ask for "No Antenna" and "hiding the electronics" but the laws of physics ask for radiation i.e. visibility of the waves in order to establish communication.

This paradigm looks like wanting to hide the

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lamp bulb away and still asking for the best visibility. *Remember: radio waves are the same as light waves.*

Yes it *is* possible to find a good, working trade-off, but you really must know what you are doing!

What influences RF Bahaviour

Even given a well designed RF electronic module, still a lot influences network performance in the field, like:

- Way of mounting the RF unit in the luminaire
- Shape of the luminaire
- Wiring ín the luminaire
- Materials of the luminaire
- the positioning of the luminaire in the field
- When mounted in the ceiling, the material of the ceiling, height, material of the floor beneath, etc.
- Inventory in the room where the luminaires has been placed (chairs, cupboards, tables, ...)
- On greater distances: the relative humidity of the air (specially at 2.5 GHz)
- And so on ...

RF, a Way of Life

RF is so different from what we were used to. It looks like “a way of life'... It asks for a different attitude towards the design cycle. *Best is to start looking at the RF properties as early as possible in the design phase*. Since geometry, materials, all influence behaviour.

- Work together with the artist that designs the 'looks' of the luminaire. Start in an early stage of the design cycle!
- Gather information from beta test sites and establish your own standards for radiation patterns, transmitted power and receiver sensitivity based on measurements on your luminaires and statistical data on performance
- **Measure, measure, measure... do not guess!** This applies for:
  - Antenna impedance and matching.
  - 3D radiated power / radiation pattern
  - TRP (total transmitted power)
  - 3D receiver sensitivity
- If you are designing several luminaires a year, investing in a set-up to measure 3D patterns and radiated power will pay itself back very fast.
  From doing the measurements you will get a lot of hands-on training and practical RF-expertise.
- Measure the radiation performance of a mock-up of the luminaire *in an early phase*. Try different solutions. And try to use materials for the mock-ups that come close to the final design.
- Experiment with different solution... Not just to design a product, but in first instance to *learn!* Remember, RF is probably new to you. You need no to become an antenna expert, but you'll need some basic feeling and understanding.
- Go for some consulting with an engineering house specialized in RF. And... make sure you learn from them!
- Choose the RF-module with care. Not

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only on paper. Test them, try them!

- And of course, read carefully the instructions that come with the RF-modules you are using in your design.

Radiation pattern

There is a tendency to specify the needed TRP (Total Radiated Power) Of course this is important, but far more important is to know the radiated power in the wanted direction! This asks for measurement of the Radiation Pattern along the three axis. And of course you knowing what the preferred radiation pattern would look like.

Think of a luminaire for lighting along highways. The luminaires are some 50 m apart, mostly in a straight line and they can actually 'see' each other. Energy radiated up or down will get lost, and you probably would like to have the radiation pattern in the shape of a discus.

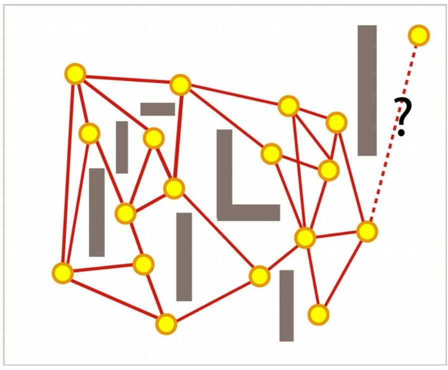
An other application, e.g. luminaires for offices, is better of with an omnidirectional radiation pattern, making use of the many reflections in most offices.

Some Rules of the Thumb

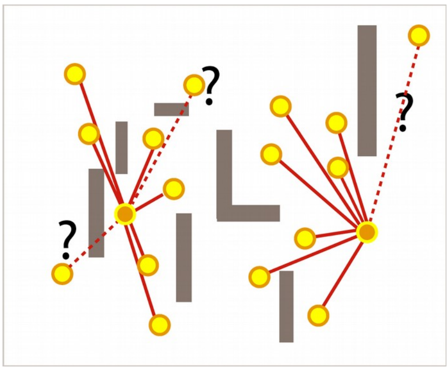
It is impossible to give a set of design rules that will guarantee a good design RF-wise. Designing in antennas in luminaires is more an Art & Craft then rocket science.

Rules of the Thumb if combined with some basic understanding are far more useful than equations and computer models.
*) state of the art 2015 of computer modelling

So here some things to take into account:



***mesh network**: more overhead and communication but also more redundancy*



***star network**: less overhead and communication but less redundancy*

- Choose the network topology with care, e.g. *Star* or *Mesh*. This greatly depends on the application in the field! This has of course to do with the module you are going to use.

- Metal enclosures can *shield* RF energy. If you use metal in your design, make sure the RF energy can come out. That can be done by holes and sleeves of the right size and position. Dimensions and placing of these holes can be very critical.

- Mounting an antenna near metal objects can severely influence antenna performance, radiation pattern, a.s.o

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- Metal sheet can act as a reflector, focussing RF energy more or less in one direction. The direction also depends on the distance of the antenna (in the module) to the metal.
- Mounting an antenna near to an insulator, like plastics and ceramics, can influence antenna behaviour. It lowers the resonance frequency which can cause mismatch of the antenna to the electronics.
- Measure 3D antenna radiation patterns and look for dead spots in the diagram. Avoid 'blind spots” in the radiation pattern, because they will hamper reliable communication.

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