「課程博士用」

学位論文の要約

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学位論文題目 Eliminate Crosstalk Using Symmetry in MIMO Arrays of Inductive Antennas: The Pie-Chart Antennas

（英訳又は和訳 誘導アンテナの多入力・多出力配列における対称性を用いたクロストーク（漏話）の除去：「パイチャートアンテナ」 ）

導入（Introduction）

What if we could increase data rate while reducing bit error rate, development time and production cost of wired and wireless signal transmissions systems? Whoever ever had a conversation in the middle of a noisy room can understand how badly crosstalk can affect a communication system. Crosstalk is a form of noise. It is a major concern in electronic design. As our communication systems grow in size and complexity, so does the crosstalk suppression issue. And with it, the complexity and/or the price of the solutions. Through this thesis, I present my piece of solution to effectively reduce crosstalk at low cost within multichannel transmission systems: namely the Pie-Chart antenna concept.

背景（Background）

Slip rings are very popular for transmitting high power or multiple signals in a small package. However, not only they are subject to the same electromagnetic design challenges as wireless devices at high frequency (e.g. electrical path length, impedance matching, crosstalk, …) but they also require periodic servicing due to mechanical wear. On the other hand, wireless data transmission protocols such as Bluetooth or W-LAN are currently not suited for wireless transmission of substantial electric power. As a result, Near-Field electromagnetic transmission systems are increasingly considered as viable alternative solutions to transmit power and information over an air-gap. At the foundation of this research was a simple non-contact slip ring I built with the idea of reducing the crosstalk between its power data channels. The pie-chart antenna concept arose from an effort at generalizing the principle used in this primary device: the use of symmetry.

目的（Objectives）

The Pie-Chart antenna concept is a simple yet effective method of designing arrays of antennas so that emitters and receivers can communicate through highly independent transmission channels. A Pie-Chart channel is defined by its order of symmetry around a longitudinal axis, thus describing an axis-symmetric azimuthal emission/reception diversity pattern. A different order of symmetry around the same axis defines a physically different channel. Every pie arrays of the same order of symmetry around this axis can communicate with each other. While transmissions from arrays of a different order are heavily rejected through a passive form of destructive interference noise cancellation.

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方法（Methods）

In this research, an electromagnetic model was established using increasingly accurate laws of classical electromagnetism. Essentially, the model predicts a total elimination of crosstalk in ideal conditions. Additionally, interesting properties of pie-chart arrays were highlighted (e.g. invariance of the crosstalk suppression capabilities despite azimuthal angles mismatch, invariance with DC current/voltage bias, ...). Those predictions were put to the test through numerical evaluations and real experiments up to the limit of the test equipment.

結果（Results）

In practice, the pie-chart antenna concept appeared quite effective at reducing crosstalk within the tested bandwidth (150Hz ~ 300MHz). Up to the test results, even poorly design 3-channels Pie-Chart inductive arrays presents an Adjacent Channel Rejection Ratio typically higher than 20dB at low frequency range and as high as 85dB depending on experimental conditions. This is a significant results in that, if properly implemented, this concept may greatly improve the signal to noise ratio in wired and wireless communication system. Especially, it may help in efficiently design harnesses carrying high power signals and low power ones on separate channels (e.g. noise reduction within electric car harnesses).

考察（Consideration）

In it current state the model seems very reliable. Yet it is limited by very strict boundary conditions (the environment is supposed to be perfectly homogeneous or symmetric). This may reduce the applicability of the concept in real conditions. Therefore it might be interesting to further look into the influences of those boundary conditions to correctly characterize pie-chart devices. Moreover, the model is perfectible. It is based on laws of classical electrodynamics which we knows is superseded by laws of quantum electrodynamics. It might be interesting to look down into the implications of a fully quantized model onto the actually demonstrated properties of Pie-chart devices, or even discover overlooked ones.

結論（Conclusion）

However founded on a very primitive wireless device as an alternative to classical slip-rings, the pie-chart antenna concept revealed number of interesting properties. Within the course of this PhD I developed an electromagnetic model describing the theoretical operation of the Pie-Chart antenna concept. I set and realized numerical evaluations and real experiments which results show good agreement with the model's predictions. I discussed how could exiting devices benefit from the proposed solution. And finally, I conceptualized new applications made possible by the Pie-Chart antenna concept. Indeed, this concept is expendable past the limited frame of electromagnetism (acoustic, vibrations and wave-signals in general) and its applicability goes beyond the sole field of wireless transmission.