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論文の要約

報告番号	甲 乙 第 221 号	氏名	小島　政明
学位論文題目	Analysis of Coupled Multimode Oscillators with High-Order Nonlinearities (高次非線形特性をもつ結合マルチモード発振回路の解析)		

論文の要約

※「目的・問題提起・考察・まとめ」のように論文の構成に沿ったかたちでまとめられたもので，論文の中身が分かるもの

Coupled oscillator systems with nonlinear characteristics have shown some interesting phenomena and brought improvements to natural science and fundamental research.

It is known that two oscillators coupled with an inductor excite two different modes: In-phase single-mode and anti-phase single-mode which both coexist for some range of parameter values when each negative resistor within the oscillator has third-power nonlinear characteristics. Fifth-power oscillator systems excite four different modes: Zero-mode, in-phase single-mode, anti-phase single-mode and double-mode, which also coexist.

However, studies in the higher-order than fifth-power oscillator systems such as in the seventh, ninth, eleventh and Nth-power oscillator systems have not yet been reported.

In this study, we clarify the relationship between multimode oscillations and the degree of order of nonlinear characteristics. In particular, we investigate some phenomena in oscillator systems in detail by numerical calculations and theoretical analyses for seventh, ninth and eleventh-power oscillator systems. And circuit experiments are also done for the seventh-power oscillator systems. Finally, we conclude the relationship between multimode oscillations and Nth-power nonlinear characteristics from the research results.

As a result, we confirmed the multimode oscillations by the actual analysis as follows:

1) 2 in-phase, 2 anti-phase single-modes and 2 double-modes
2) zero-mode, 2 in-phase, 2 anti-phase single-modes and 4 double-modes
3) 3 in-phase, 3 anti-phase single-modes and 6 double-modes

in the seventh, ninth, and eleventh-power oscillator systems, respectively, coexisted and were stably excited.

From these results, we showed the relationship by conjecture as follows:

1) j in-phase, j anti-phase single-modes and j^2-j double-modes
2) zero-mode, j in-phase, j anti-phase single-modes and j^2 double-modes

for N_nth and N_pth-power oscillator systems, respectively (where j = 1, 2, ..., N_n = 4j-1, N_p = 4j+1).

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論 文 内 容 要 旨

報告番号	甲 先 第 **２２１** 号	氏 名	小島 政明
学位論文題目	Analysis of Coupled Multimode Oscillators with High-Order Nonlinearities (高次非線形特性をもつ結合マルチモード発振回路の解析)		

内容要旨

Coupled oscillator systems with nonlinear characteristics have shown some interesting phenomena and brought improvements to natural science and fundamental research. One of the interesting phenomena is synchronization. Hence, some studies of synchronization phenomena have been reported in physical and biological systems.
Other studies have also been reported in electrical systems as follows.

It is known that two oscillators coupled with an inductor (or a capacitor) excite two different modes: In-phase single-mode and anti-phase single-mode which both coexist for some range of parameter values when each negative resistor within the oscillator has third-power nonlinear characteristics. Fifth-power oscillator systems (the coupled oscillators with fifth-power nonlinear characteristics) excite four different modes: Zero-mode (non-oscillation), in-phase single-mode, anti-phase single-mode and double-mode, which coexist for some range of parameter values. The double-mode is an anomalous oscillation in relatively simple circuits and means that two single-modes (in-phase and anti-phase) oscillate, simultaneously and asynchronously. Other types of double-modes (multifrequency: in-phase and out-of-phase) have been reported. They have aimed to apply multifrequency patterns to active array antenna systems. Our work can provide the double-mode oscillation in a very simple circuit model and therefore contribute to the active array antenna fields. Furthermore, many variations of the coupled oscillator systems made by increasing the number of oscillators or changing coupled elements and structures have been investigated. In some of these oscillator systems, the double-mode has also been reported.

We investigated ninth-power oscillator systems and reported that three types of double-mode oscillations were stably excited. However, we have now found that more than three types of double-mode oscillations are stably excited in this study. Furthermore, we mention the relationship between the number of different amplitude modes and high order oscillator systems which could not be reported in former studies.

In this study, we investigate some phenomena in oscillator systems in detail by numerical calculations and theoretical analyses for seventh, ninth and eleventh-power oscillator systems. And circuit experiments are also done for the seventh-power oscillator systems. Finally, we conclude the relationship between multimode oscillations and Nth-power (N=2m+1, m=1,2,..) nonlinear characteristics from the research results.

In chapter 2, we propose a circuit model. This circuit model consists of two van der Pol oscillators with Nth-power nonlinear characteristics coupled with an inductor. We also set up general circuit equations with Nth-power nonlinear characteristics from this model. These circuit model and equations can apply to chapters 3-6.

In chapter 3, we investigate multimode oscillations in the seventh-power oscillator systems by numerical calculations, circuit experiments and theoretical analyses in detail. We also confirm that these multimode oscillations are stably excited when changing the parameter values for the oscillator systems. We find some different oscillation modes in the seventh-power oscillator systems compared with those in the fifth-power oscillator systems.

In chapter 4, on the basis of the oscillation modes in third, fifth and seventh-power oscillator systems, we also investigate multimode oscillations in the ninth and eleventh-power oscillator systems by numerical calculations and theoretical analyses. We also find some different results in those oscillator systems. We make preparations for materials in order to consider the regularity for Nth-power oscillator systems.

In chapter 5, we predict the relationship between the multimode oscillations and Nth-power nonlinear characteristics from the results of chapters 3-4, explaining the physical reason for these phenomena. In particular, we discuss the reason of the increase for the oscillation modes while increasing the number of order of nonlinear characteristics.

In chapter 6, we investigate multimode oscillations in the thirteenth and fifteenth oscillator systems by numerical calculations to confirm if our conjecture in chapter 5 agrees with the results for higher than eleventh-power oscillator systems.

Finally, in chapter 7, we summarize the relationship between multimode oscillations and the degree of order of nonlinear characteristics and consider our future studies.

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論文審査の結果の要旨

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学位論文題目 Analysis of Coupled Multimode Oscillators with High-Order Nonlinearities

（高次非線形特性をもつ結合マルチモード発振回路の解析）

審査結果の要旨

本論文は高次非線形特性をもつ結合発振回路においてマルチモード振動の解析を行ったものである。

背景として、結合発振回路の研究において、これまで結合素子やパターンを変えたものや大規模化したものなど様々なモデルで解析されてきた。一方、発振回路のエネルギー供給部である負性抵抗において、その特性や次数を変えたときの現象解析は十分にされていない。その理由の１つとして、とりわけ高次の結合発振回路において、一般解を導出し、系の安定判別が困難であることが考えられる。

本論文では、一般解の導出ではなく、係数パラメータに特定の値を与えることで系の安定判別を行い、工学的観点から非線形特性の次数とマルチモード数の関係性を導いたことに新規性がある。

具体的には、7次の非線形特性をもつ結合発振回路におけるマルチモード振動の解析(数値計算、回路実験、理論解析)を行い、9次、11次のシステムでも同様に解析(数値計算、理論解析)を行った。得られた結果から物理的説明のつく形で、N次のシステムにおけるマルチモードの種類と数を導出した。最後に、13次、15次のシステムでも同様に解析(数値計算)を行い、N次システムで導出した式と数値計算結果で出たマルチモードの数が一致することを確認した。

以上本研究は，今後の結合発振回路システムの研究の発展に有効であり，本論文は博士（工学）の学位授与に値するものと判定する。