行政院國家委員會專題研究計畫成果報告

毫米波電路與天線(II)子計畫三：注入鎖定主動天線陣列(3/3)
Injection-Locked Active Antenna Array (3/3)

計畫編號：NSC89-2213-E-002-050
執行期限：88年8月1日至89年7月31日
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一、 中文摘要

本計畫旨在建立注入鎖定主動天線陣列之理論分析、模擬與實驗量測，以及N-埠網路S-參數之量測原理、校準、裝置與應用。

本報告係敘述第三年之研究成果，包括：1、建立天線耦合效應之陣列分析方法，2、使用諧波平衡法，建立分析注入鎖定自我振盪倍頻器，及主動天線陣列之理論、模擬與實驗量測，3、建立N-埠網路S-參數之降埠量測方法，於天線特性量測之應用。

關鍵詞：注入鎖定、自我振盪倍頻器、主動天線陣列、N-埠網路S-參數量測技術、天線特性。

英文摘要

The purpose of this three-year research project is to develop the basic theory, numerical simulation and experimental measurement of an injection locked active antenna array and the basic principle, calibration, arrangement and measurement of the S-parameter of an N-port network.

In this third-year report, the study results include: (1) analysis of finite antenna array including mutual coupling effects, (2) using harmonic-balance method to study the injection-locked self-oscillating doubler and active antenna array, (3) developing the port reduction method for S-parameter measurement of an N-port network and its applications on antenna measurement.
Key words: injection locking technique, self-oscillating doubler, active antenna array, N-port network S-parameter measurement technique, antenna measurement.

二、 計畫緣由與目的

Using active array structure with each element consisting of an antenna and a solid state oscillator is a practical approach to construct a microwave or millimeter wave spatial power combiner (or source). In order to coherently combine these solid state sources to generate high output power, the oscillators are usually injection locked to a reference signal. This then leads to the structure of an injection locked active antenna array (ILAA).

Two-port vector network analyzer (for example, HP8510C) is a well-known two-port S-parameter measurement instrument. For an N-port network (for example, ILAA), its S-parameter is then usually acquired by using HP8510C for each selected two-port pair and all other ports are terminated with perfectly matched loads. However, this measurement technique is not valid and may degrade the S-parameter measurement performance for an N-port device as the operating frequency increases.

The objective of this three-year research project has two. One is to develop the basic theory, numerical simulation and experimental measurement of an injection-locked active antenna array. Two is to develop the basic principle, calibration, measurement arrangement and applications for the S-parameter measurement technique of an N-port network.

In the following section, we will briefly describe the approaches and results developed in this third-year study.

三、研究方法及成果

In this third year, we firstly develop an approach to optimize the gain performance of a dipole array as shown in Fig.1 (a) by adjusting the dipole element spacing using the boundary-following method of gradient technique. The dipole antenna array considered here is given as an example of the antenna array for ILAA shown in Fig.1 (b). In the optimization, the mutual coupling effect in dipole array is modeled based on a power series expansion approach. This optimization algorithm is shown numerically efficient, especially in the use of large antenna array design.

For the active antenna array study, in this year we developed a novel design of self-oscillating doubler and active doubler antenna array. Both self-oscillating doubler and active doubler antenna array are based on the injection-locking approach, therefore, they can yield with a very high conversion gain. This injection-locked self-oscillating double (ILSOD) is analyzed using harmonic-balance (H-B) method to calculate its output spectrum and locking bandwidth. Simulation results are shown in good agreement with measurement results. For active doubler antenna, the patch antenna is shown not only a radiating element but also a resonator to reject the fundamental frequency in the self-oscillating doubler. The active doubler antenna is shown to be a beam scanning antenna array.

The ILSOD and active doubler antenna are designed using NE32684A low noise package-type PHEMT. The substrate has ε_r=2.5 and 62mil in thickness. As shown in Fig. 2 (a) and (b), both ILSOD and active doubler antenna use a series feedback to cause oscillation. In order to enhance the doubler output power, two different lengths of microstrip lines L1 and L2 are designed at the PHEMT source terminal. L2 is of quarter-wavelength long at the fundamental frequency. Hence, it becomes an open circuit, and L1, which is of shorter length, determines the oscillation frequency. For a series feedback oscillator, point A in Fig. 2(a) is required to have a low impedance. A five-section high-low impedance quarter-wavelength transformer is then designed at the output port. At the second harmonic (or doubler output) frequency, the PHEMT is source grounded to reduce the feedback loss, and the quarter-wavelength transformer becomes the output matching circuit.

For the active doubler antenna design, the high-low impedance transformer is replaced by a rectangular patch antenna with resonant frequency at the second-harmonic frequency as shown in Fig. 2(b). The patch feed line is then properly designed to have low impedance at point A as that for the ILSOD. As for the active doubler antenna array design as shown in Fig.3 (a), in order to have a wider locking bandwidth of ILSOD; a resistive circuit is added at the gate port of each active antenna element.

In the measurement of active doubler antenna performance, the radiation power of active doubler antenna is measured with a spectrum analyzer. The measurement system is calibrated with reference horn antennas. The EIRP of active doubler antenna is then calculated using the Friis formulation to give about 14.4 dBm at 5.9 GHz. This agrees with the predicted value, since the patch antenna has a gain about 8.77 dB and ILSOD output power is about 5.63 dBm. The injection signal is –20 dBm at 2.95 GHz, hence the conversion gain is about 35 dB.

The measurement results of active doubler antenna array with beam scanning performance are given in Fig. 3 (b). They are shown that as the free-running frequency of each ILSOD is tuned, the array H-plane pattern can be scanned in positive or negation direction as a beam scanning array.

Thirdly, for the study of applying port reduction method to the antenna measurement, in this year, we developed a quasi-monostatic arrangement, in which three antennas are arranged as the transmitting, receiving and reflecting antennas shown in Fig.4 (a). It can be represented as a three-port network shown in Fig. 4 (b). By measuring the two-port scattering parameters at the reference planes of transmitting and receiving antennas while the reflecting antenna is terminated with three different terminators, the three-port scattering parameters can be calculated. One can then follow the three-antenna method to find the gain of each antenna. In addition, the structural scattering characteristics of each antenna can be solved.

四、結論與討論

In this third year report, study results of (1) analysis of finite antenna array including mutual coupling effects, (2) an injection-locked self-oscillating doubler and active antenna array, (3) antenna gain and structual measurements using the port reduction method are presented. This work not only is a basic research study, but also finds applications in the areas of stable source, nonlinear or active array, multiport MMIC, device or antenna measurement techniques.

五、 發表論文

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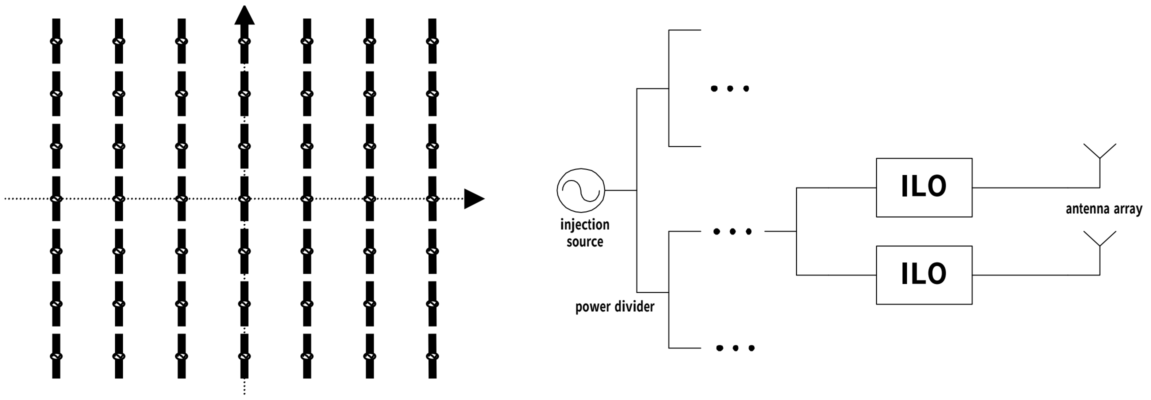


Fig.1 Schematic diagrams of (a) a dipole array and (b) an injection locked antenna array (ILAA).

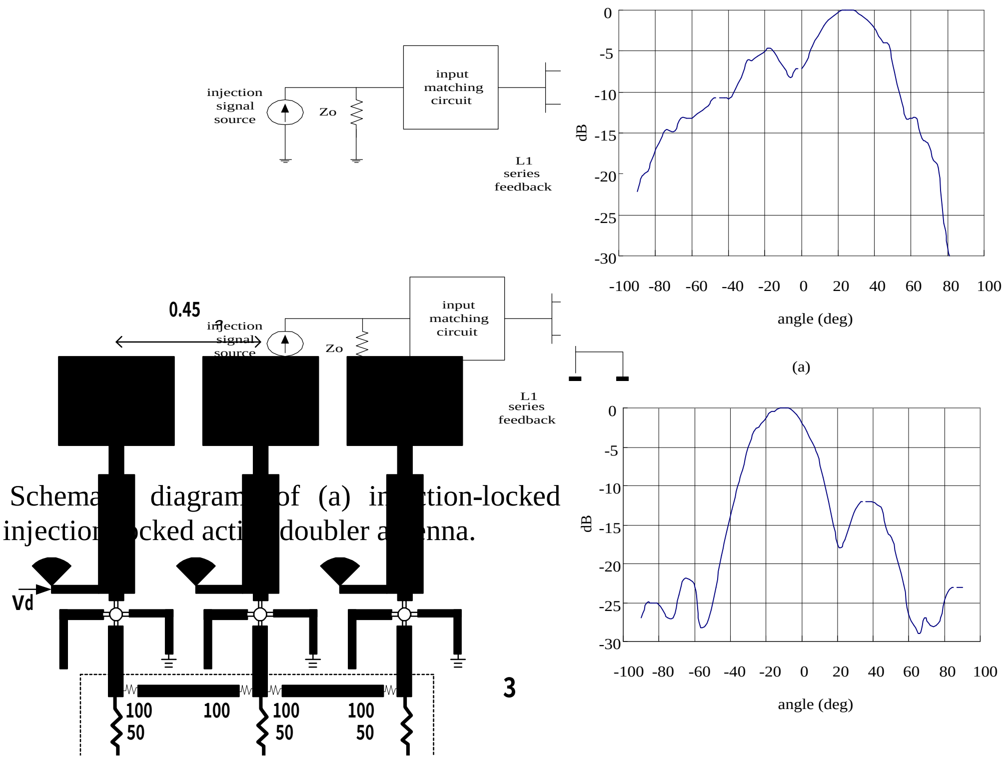
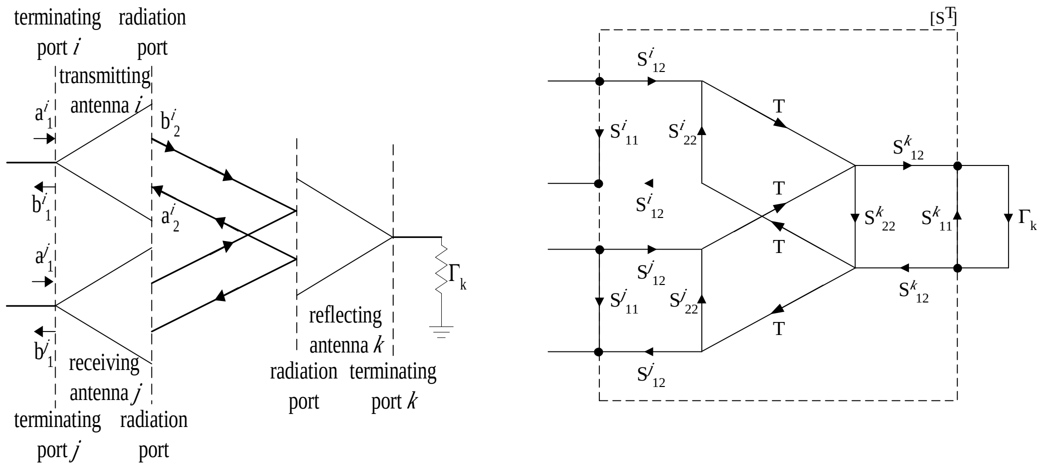


Fig.2 Schema diagram of (a) in tion-locked and (b) injection cked acti doubler a nna.

Fig.3 (a) Injection-locked active doubler antenna array and (b) measurement results of radiation pattern.



(a) (b)

Fig.4 Schmatic diagrams for (a) antenna gain and scattering measurement using port reduction method and (b) its equivalent three-port network.

(a) (b)