ANALYSIS AND MEASUREMENT OF LARGE DYNAMIC RANGE RF SWITCH INTER-MODULATION

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Abstract Radio Frequency (RF) switch circuit is the basic part of microwave devices and systems. The non-linearity distortion figure is necessary in the field of large dynamic range of signal. This letter analyzes the basic switch circuit and its inter-modulation, and studies in detail the measurement methods and systems of RF switch intercept point. It has provided cascaded simulation testing methods, which can accurately measure the PF switch, of which the second or third order intercept point value is above 75dB and 60dB, respectively. As the testing results are consistent with the theoretical analyses, it proves that the validity of the method satisfies the requirements of large scaled linearity measurement in engineering.

Key words Large dynamic range Radio Frequency (RF) switch; Intercept point; Measurement

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I. Introduction
Radio Frequency (RF) switch circuit is a basic part for equipment and RF systems, such as transmitter, receiver and interchangeable matrixes, etc. The non-linear indicator of RF is one of the key factors that influence the RF system and the performance of equipments. The most commonly-used component of RF switch is the Positive-Intrinsic-Negative (PIN) tube, whose non-linearity constitutes the fundamental cause of the non-linearity of the switch. Within a cascaded system, the switch unit is usually in the front party, so its influence on the non-linearity of the system is the most noticeable one. How to design and realize the non-linear indicator of switch circuit has been a usual technical problem in the field of engineering[1-3]. Since there is not any specialized instrument for testing the inter-modulation, it is usually measured by relating several relative instruments. Generally speaking, it is necessary to have at least two sources of signal, a signal synthesizer and a spectrum analyzer, constituting a cascaded testing system. As is limited by the dynamic range of the testing instrument and the degree of noise, it is comparatively difficult to test the 3rd order intercept point above +55dB. On the occasion of applying a highly linear system, there is still no convenient or accurate testing method at present, which has brought much trouble for project designing. This letter analyzes the non-linearity of RF switch, and by conducting experiments and research, provides an effective and accurate testing method for engineering application.

II. PIN Switch Circuit
As the PIN tube has impedance, either turn-on or turn-off, with direct current and back bias, a microwave switch has successfully controlled the channel-transformation of microwave signals. The Direct Current (DC) voltage-current characteristic of PIN diode is the same as that of PN junction diode, but they are fundamentally different within the microwave frequency band. As the total charge on the I layer of PIN diode is mainly generated by the bias current, but not by the instantaneous value of microwave current, there is only one linear resistance to its microwave signal. This resistance, which is determined by DC bias, is low when the bias is positive, and high when in a short circuit, which is almost open circuit. Therefore, PIN diode has no linear rectifying effect on microwave signals, which is the fundamental difference between PIN
diode and the ordinary diodes. Due to this characteristics, PIN diode is suitable for components microwave controlling. PIN diode is also non-linear, so it can generate inter-modulation. When PIN switch is used in broadband system, the harmonic wave may be located within the frequency-band and cause interference. Based on the current type, PIN switches fall into two categories, reflective type and absorptive type. Since the reflective switch realizes isolation by means of reflected signals, the standing wave is small only in a state of turning-on. In contrast, the absorptive type can absorb the power by its own absorption charge, the standing wave is comparatively small both in the states of turning-on and turning-off. However, when the power handling capacity is concerned, the latter type is not as good as the former. Therefore, either the serial circuit or the parallel circuit is often used in the low section of microwave, only parallel circuit is used in the high section of microwave\(^4\). The diagram of reflective Single-Pole Single-Throw (SPST) PIN switch is showed in Fig.1, while that of absorptive one in Fig.2.

Microwave PIN switches are often designed as SPMT, the more the throws, the more sophisticated the technology, and the more difficult to have high index. The main reason for this is that it is not easy to guarantee such indexes as isolation and standing wave at the synthesis terminal. In real system, the circuit of a switch is often connected to the RF-output circuit in power-dividers or amplifiers. Whether the PIN switch is selected or not, it is a necessity to have a relatively good loading capacity, so the absorptive PIN switches are the most frequently applied.

**III. Analysis of Inter-modulation of the Switch**

The component of inter-modulation is an important non-linear index affecting the performance of a switch. When several single tone signals are added to the non-linear devices, a linear combination of several frequencies may appear in the non-linear devices, causing inter-modulation. As the inter-modulation frequency is too close to the signal frequency to filter from the wave digital filter, a false signal may occur in the channel, seriously affecting the testing and identifying of signals in the system\(^5\). According to Fourier series, the formula for acquiring the maximum 2rd and 3rd inter-modulation components relative to spectrum energy are as follows:

\[
\alpha_2A^2 \left[ \cos(\omega_1 - \omega_2)t + \cos(\omega_1 + \omega_2)t \right] \quad (1)
\]

\[
\frac{3\alpha_3A^3}{4} \left[ \cos(2\omega_1 - \omega_2)t + \cos(2\omega_2 - \omega_1)t \right] \quad (2)
\]

In the above formulae, \(\omega_1, \omega_2\) are the respective single tone signal, and \(A\) is the signal level, with \(a_2\) and \(a_3\) respectively the coefficients of two degree term and three degree term.

Obviously, on the occasion of a stable input signal level, the smaller the inter-modulation component, the more remarkable the linearity of the system. Therefore, it is feasible to measure its linear degree with the value of the inter-modulation component. However, from the above formulae, the value of the inter-modulation component is not only related to the linear degree of the system, but also to its input signal level. The unqualified prin-