Microwave Group Delay Time Adjuster

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Abstract — **This paper presents a method to control group delay time using a resonance circuit. The group delay time adjuster(GDTA) that can control signal group delay time comprises a variable capacitance and a variable equivalent inductor. These are coupled in parallel at a node and also controlled by two bias voltages separately. A variable equivalent inductor is realized a transmission line terminated a variable capacitor. Group delay time can be controlled by change of capacitance and inductance, but the resonating frequency is fixed. When the proposed GDTA is fabricated on RFID Korean frequency band (908.5~914MHz), a group delay variation is obtained about 3ns.**

Index Terms — **Group delay, resonance circuit, virtual inductor, varactor diode.**

I. INTRODUCTION

When an electrical system has a linear characteristic, a signal traveling without distortion is achieved, If an electrical system has a nonlinear characteristic, a nonlinear output signal can be explained AM-to-AM, AM-to-PM, intermodulation distortion (IMD), adjacent channel power ratio (ACPR), etc. For the nonlinear output, several linearizing techniques have been introduced until now [1][2]. In using a predistortion and a feedforward technique, group delay matching and adjusting in addition to amplitude and out-of-phase matching is very important. It is widely in use to a variable attenuator and phase shifter for magnitude and phase control [3][4].

Also a feedback interference signal generated from transmitter (Tx) antenna to receiver (Rx) antenna deteriorates the signal performance of receiver system and results the co-channel interference in the repeating system. The delay time of the co-channel interferer from Tx to Rx is different case by case and on environment condition. The amplitude, the phase, and the electrical delay time of the correction signal have to be controlled to cancel interferer broadband interferer effectively [5][6].

Until now, there are few GDTAs in microwave circuit. The GDTA that consists of different paths having different physical length of a transmission line had been introduced [7]. But the previous GDTA couldn't control group delay time adaptively. In this paper, the GDTA that can control a signal group delay time is proposed. The proposed GDTA plays a key role in a number of applications which require compensation for group delay.

II. ADJUSTABLE GROUP DELAY THEORY

A group delay is a measure of how long it takes a time to traverse or transit a system. It is a strong function of the length of the system, and usually a weak function of frequency. It is expressed in units of time.

In general, the changing rate of the total phase shift with respect to angular frequency is called the group delay (*G.D.*), defined as below [8].

$$G.D. = -\frac{d\phi}{d\omega} \tag{1}$$

where Φ and ω are the total phase shift and the angular frequency, respectively. Also, group delay is expressed differential equation of phase variation at the operating frequency and it is an important parameter for observing linear phase distortion of receive, transfer signal, data, and so on.

We should analyze the resonance circuit shown as Fig. 1. The input admittance looking into the parallel resonance circuit is expressed as Eq. (2) and the transmission characteristics can be expressed as Eq. (3).

$$Y_{in} = Y_0 + j\left(\omega C - \frac{1}{\omega L}\right) \tag{2}$$

$$S_{21} = \frac{2Y_0}{\sqrt{4Y_0^2 + (\omega C - 1/\omega L)^2}} \exp\left(j\left(\tan^{-1}\frac{1-\omega^2 LC}{2\omega L Y_0}\right)\right) \tag{3}$$

From Eq. (3), the differential coefficient of the phase component with respect to angular frequency is shown at Eq. (4).

$$G.D. = \frac{2Y_0 L\left(1+\omega^2 LC\right)}{4\omega^2 L^2 Y_0^2 + \left(1-\omega^2 LC\right)} \tag{4}$$

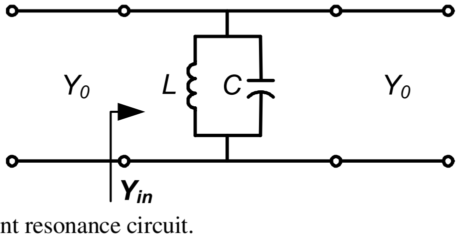

Fig. 1. Shunt resonance circuit.

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If the parallel resonance circuit maintains the particular resonance frequency, $\omega_0^2 LC=1$, then the transmission characteristics maintains constant characteristics. But the group delay time can be expressed as Eq. (5).

$$G.D. = \frac{1}{\omega_0^2 Y_0 L} = CZ_0 \qquad (5)$$

From Eq. (5), we notice that the more capacitance increase, the more group delay time increase. On the contrary, the more inductance increase, the less group delay time decrease. If the resonant frequency maintain constantly, group delay time will be able to be adjusted by combination of capacitance and inductance.

III. FABRICATION AND MEASUREMENT OF GDTA

A. Varactor diode measurement

A varactor diode is a semiconductor device that is widely used in the many applications which a variable capacitance is required. The operation of the varactor diode is based on the fact that a reverse biased PN junction acts as a small variable capacitor. So a variation of capacitance is due to the junction voltage.

Fig. 2 is shown diode capacitance of 1T362 of Sony versus reverse voltage. It has a variation of about 2.3pF to 100pF.

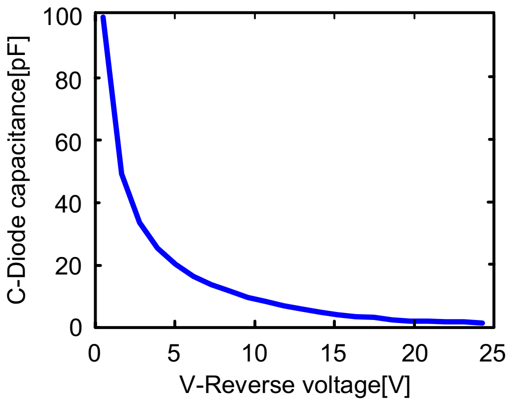


Fig. 2. The capacitance measurement of the varactor diode, 1T362 of Sony.

B. Variable equivalent inductor and GDTA unit

There are few variable inductors in microwave devices. Even though there is an active inductor using a gyrator structure, but a quality factor of the active inductor doesn't have a high enough value and changed according to control voltage. So this device isn't widely used yet [9]. The series combination of a lumped inductor and a varactor diode shown in Fig. 3 (a) can be operated as the variable inductor. But it is difficult to take the inductor that a self resonance frequency (SRF) is large enough in microwave frequency. Also the fabricated inductor is unsuitable because it has much tolerance. A low characteristic impedance transmission line terminated with the varactor shown in Fig. 3 (b) can be operated as the variable inductor. If the operating frequency is low enough, then the physical length of transmission line is too long.

(a) (b)

Fig. 3. The kinds of the variable inductor.

To implement the variable inductor, the high characteristic impedance transmission line terminated with the varactor is used. Fig. 4 shows a lumped element equivalent circuit of the transmission line. The high characteristic impedance and the electrical angle of the transmission line are Z_t and , respectively. And the value of the lumped elements can be represented as below.

$$L_t = \frac{Z_t \sin\theta}{\omega}, \qquad C_t = \frac{1-\cos\theta}{Z_t \omega \sin\theta} \qquad (6)$$

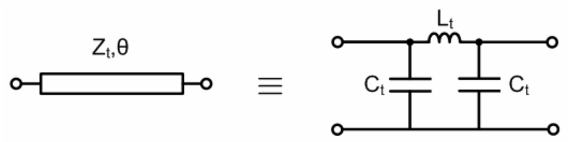


Fig. 4. A transmission line and a lumped element equivalent circuit.

We propose a GDTA unit shown in Fig. 5. The varactor diode is operated as the variable capacitance and the transmission line terminated the varactor diode is operated as the variable equivalent inductor.

The implementation process of the variable equivalent inductor is represented at Fig. 6. The C_1 and C_2 are capacitances of varactor diodes which are used for implementation of a variable capacitor and variable inductor, respectively.

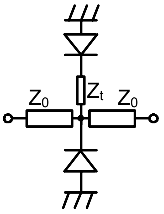
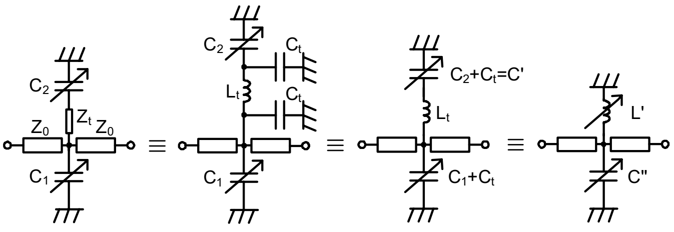


Fig. 5. The proposed GDTA unit.



(a) (b) (c) (d)

Fig. 6. The equivalent circuit of the GDTA using the transmission line.

It replaced the transmission line for the virtual inductor with a lumped element equivalent circuit as shown Fig. 6 (a) and (b). We should combine C_1 and C_2 of the varactor diode with C_t of a lumped element equivalent circuit of a transmission line, respectively, and it is represented by Fig. 6 (c). When the capacitor (C') coupled to inductor L_t was combined, we could obtain a variable equivalent inductance characteristic as (d). Eq. (7) shows the equivalent reactance of the transmission line terminated with the varactor. As long as the equivalent reactance (X_L) is positive, it has an inductive characteristic. Therefore, as C' is varied, we could obtain a variable inductance characteristic.

$$X_L = \frac{\omega_0^2 L_t C' - 1}{\omega_0 C'} \tag{7}$$

The capacitance variation requirement is about 20pF for 1ns group delay variation in case the characteristic impedance is 50Ω due to Eq. (5). The value of the variable capacitor and the equivalent inductor are controlled by two bias voltages, and that is must satisfied with the resonant condition. As the resonant frequency is maintained constantly, a capacitance is in inverse proportion to an inductance. Therefore, group delay is changed. The GDTA unit is tested in 911MHz. The measurement results are shown in Table I.

TABLE I
THE GDTA UNIT MEASUREMENT RESULTS (@911MHz)

***G.D.*[ns]**	**S21[dB]**	**S11[dB]**
0.420	-0.23	-31.40
1.420	-0.77	-21.30
2.468	-1.45	-16.30
3.479	-2.20	-13.10

C. The Balanced GDTA

In order to obtain better reflection characteristics of the GDTA, a balanced GDTA is proposed and shown in the Fig. 7. The fabricated GDTA is tested on RFID Korean frequency band (908.5~914MHz). The measurement results of the proposed balanced GDTA are represented at table II and Fig. 8 according to group delay variation.

Although, we could obtain more the group delay time variance, the transmission characteristic and the group delay time flatness in the high group delay time region are so bad that we have no choice but to accept a variation range of the group delay time as 3ns. Where the transmission coefficient (S_{21}) flatness is less than 0.1dB and the maximum reflection coefficient is -24.4dB.

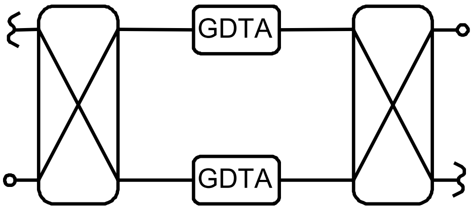
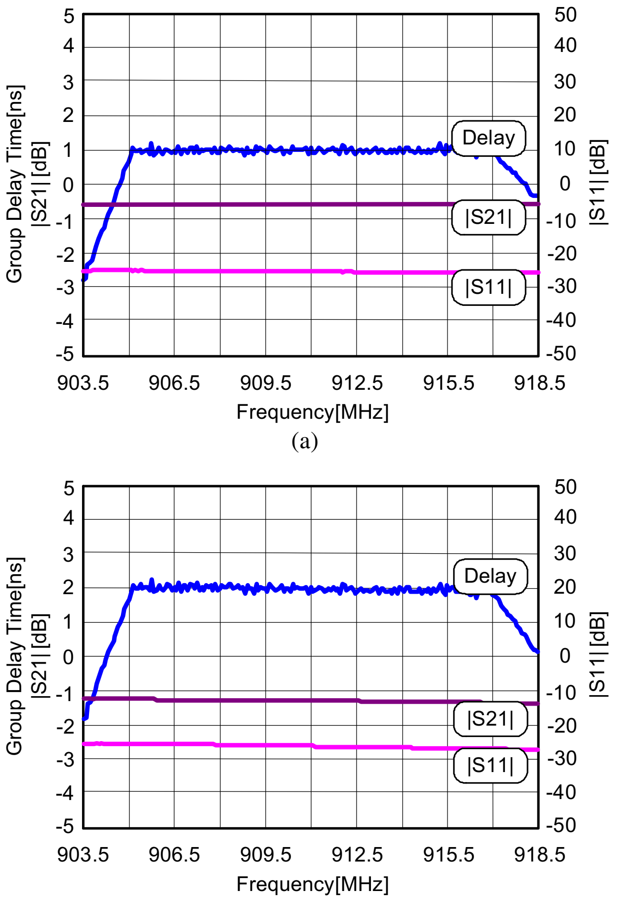


Fig. 7. The proposed balanced GDTA.

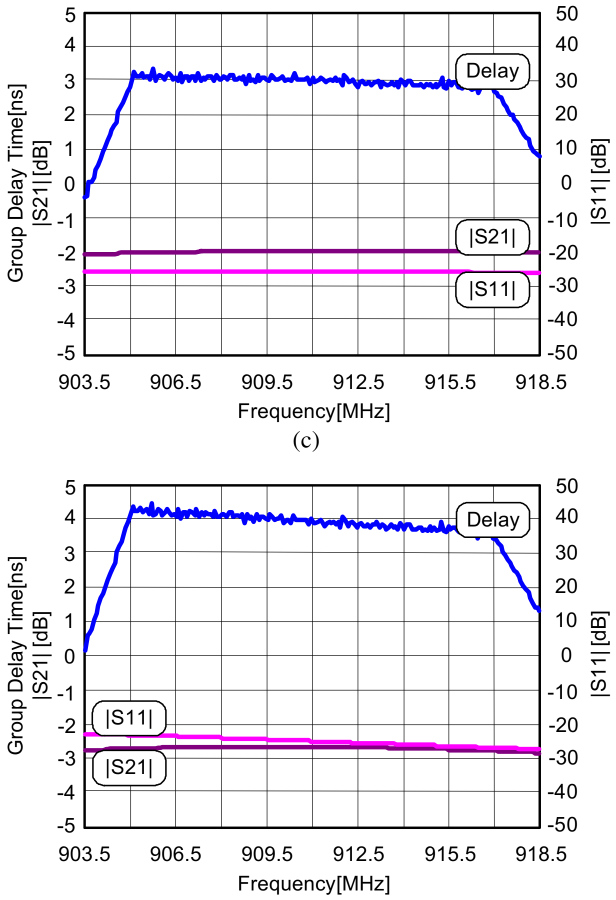
TABLE II
THE BALANCED GDTA MEASUREMENT RESULTS

***G.D.*[ns]**			**S21[dB]**			**S11[dB]**
908.5 MHz	**911 MHz**	**914 MHz**	**908.5 MHz**	**911 MHz**	**914 MHz**	**911 MHz**
1.005	1.041	1.025	-0.65	-0.64	-0.64	-25.65
2.000	2.010	1.970	-1.36	-1.37	-1.39	-26.74
3.051	3.077	2.986	-1.96	-1.95	-1.95	-24.84
4.021	3.938	3.792	-2.68	-2.68	-2.71	-24.41



(a)

(b)



(c)

(d)

Fig. 8. The electrical characteristics of the balanced GDTA.

IV. CONCLUSION

We designed the GDTA that is able to adjust the group delay time using the resonance circuit with a variable capacitance and a variable equivalent inductance. As the resonant frequency of resonance circuit is maintained constantly and the capacitance is varied, the group delay time can be adjusted. We proposed the balanced GDTA, because the single GDTA unit doesn't have enough low reflection characteristics. We could obtain the better reflection characteristics with balanced structure, but even so group delay time is varied from 1ns to 4ns. In next, we have a plan to apply the GDTA to the wireless repeater system using a co-channel interference cancellation technique and the feedforward circuits for a good linearity. We feel confident that the GDTA contribute not only improvement in a quality of communication, but also in a fabrication of communication system.

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