Group Delay Adjuster Using Resonance Circuit with Varactor Diode

Sang-Keun Park, Jin-Kuk Lee, Yong-Chae Jeong, Jae-Hun Yun*, Chul-Dong Kim**
Dept. of Information & Communication Engineering, Chonbuk National University,
664-14, Duckjin-Dong, Duckjin-Gu, Jeonju, Korea, 561-756
*Electronics and Telecommunication Research Institute, Daejeon, Korea
**Sewon Teletech Inc., Anyang, Kyounggi, Korea

Abstract — **This paper presents a method to control group delay using resonance circuit. The group delay adjuster (GDA) which can control signal group delay time comprises a variable capacitance and a variable virtual inductor. These are coupled in parallel at a node and also controlled by two bias voltages respectively. A variable virtual inductor is realized a transmission line terminated a variable capacitor. When the proposed GDA is fabricated on cellular base-station transmitting band (869-894MHz), a group delay variation range of the fabricated GDA is about 1ns.**

I. Introduction

A signal traveling without distortion is achieved, when an electrical system has a linear characteristic. If an electrical system has a nonlinear characteristic, a linear electrical signal changed into a nonlinear signal. Generally, this phenomenon is explained AM-to-AM, AM-to-PM, intermodulation distortion (IMD), adjacent channel power ratio (ACPR) etc. For a signal linearization, 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 between signals is very important.

Also a feedback 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 broadband interferer effectively.

Until now, there are few GDAs in RF circuit. The GDA that consists of different paths having different physical length of a transmission line had been introduced [3]. But the previous GDA can't control group delay time adaptively. In this paper, the GDA which can control a signal group delay time is proposed. The GDA is implemented by a resonance circuit using a variable capacitance and a virtual inductor. These are controlled by two bias voltages. For a variable capacitor, a varactor diode is used. But inductors are usually difficult to build in RF and microwave frequency, and have large tolerance. So the trimming or adjustment of inductor is required for the correct inductance value. They are typically implemented for example, by a coil of wire, a spiral of foil disposed upon a substrate or printed circuit board. So a variable virtual inductor is realized a transmission line terminated with a variable capacitor instead of a variable inductor. As bias condition is changed, a variable capacitance and a variable virtual inductor are operated so that group delay is adjusted. The proposed GDA plays a key role in a number of applications which require compensation for group delay. If an electrical system that has a variable group delay is required fixed group delay characteristic, the GDA may be added so that the overall electrical system response is more nearly constant.

II. 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.

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

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 (2) and transmission characteristics can be expressed as (3).

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

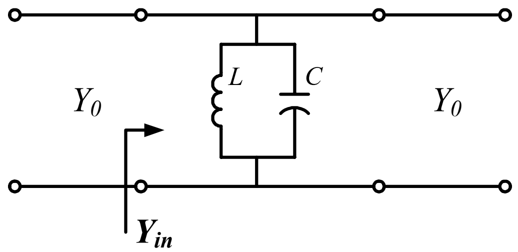


Fig. 1. Shunt resonance circuit.

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

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

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

If the parallel resonance circuit is resonated on the operating frequency, $\omega_o^2 LC=1$, then the group delay time is expressed as (5) [4].

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

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

III. Fabrication and Measurement of Group Delay Adjuster

A. Varactor diode measurement

Varactor diodes are semiconductor devices that are widely used in the many applications which a voltage controlled variable capacitance is required. Accordingly they are used in circuits including voltage controlled oscillators and filters.

Their operation is based on the fact that a reverse biased PN junction acts as a small variable capacitor. It is a variation in capacitance with voltage.

A capacitance and inductance must be adjusted independently to control group delay. To implement a variable capacitance, varactor diode, 1T362 of Sony, is used. Fig. 2 is

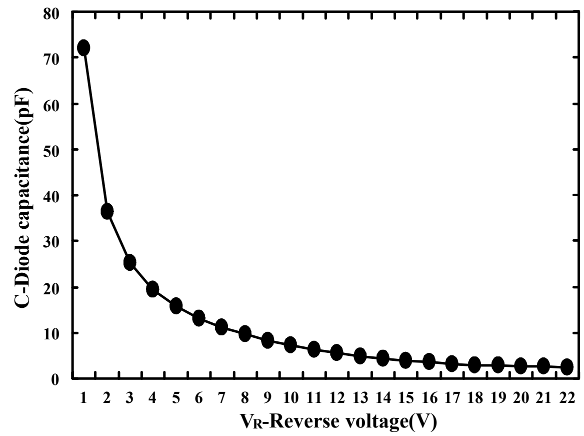


Fig. 2. The capacitance measurement of a varactor diode, 1T362 of SONY.

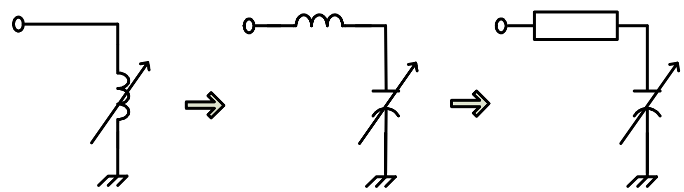


Fig. 3. Variable virtual inductor.

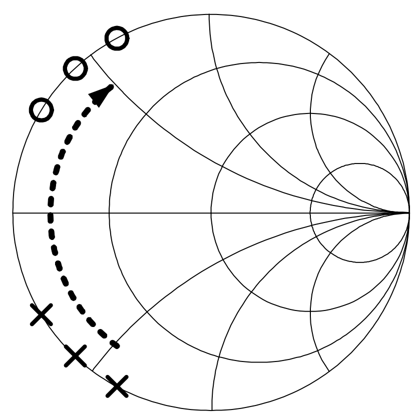


Fig. 4. The transformation of a capacitive characteristic into an inductive characteristic.

shown diode capacitance of 1T362 versus reverse voltage. It has a variation of 2.5 to 72pF.

B. Variable virtual inductor

Since it is difficult to implement a variable inductor in microwave, the fixed inductor with a variable capacitor which has an inductive characteristic is available. But since a fixed inductor has much tolerance, a transmission line terminated with a variable capacitor is used in this paper. A proposed structure is shown at Fig. 3. A transmission line shifts capacitive characteristic to inductive as like Fig. 4.

C. Group delay adjuster unit

A proposed single GDA unit using a variable capacitance

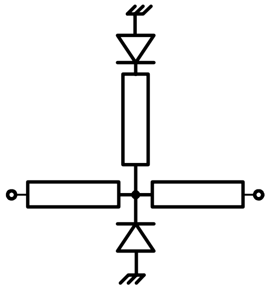


Fig. 5. The group delay adjuster (GDA) unit.

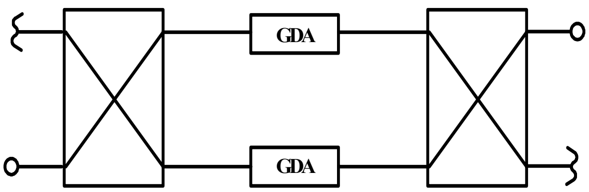


Fig. 6. A proposed transmission type GDA.

and variable virtual inductor is shown in the Fig. 5. A variable capacitance and variable virtual inductor are adjusted by two variation requirement is about 20pF for 1ns group delay variation in case the characteristic impedance is 50Ω. The GDA unit comprises a transmission line involving an input and an output terminal, a variable capacitance and a variable inductance. A virtual inductor which is a transmission line coupled a variable capacitance is coupled in parallel to the variable capacitance. The variable shunt capacitance coupled a transmission line is transformed into a variable inductance, and then the group delay is adjusted.

Two bias voltages are varied to control the desired characteristic value of a variable capacitor and virtual inductor with a variable capacitance, respectively. The value of variable capacitor and virtual inductor is controlled, and that is satisfied with resonant condition.

An equation (5) is represented that group delay is changed by a variation of capacitance or inductance. As resonant frequency is maintained constantly, a capacitance is in inverse proportion to an inductance. Therefore, group delay is changed. The GDA unit is fabricated for a cellular repeater system and a cellular feedforward amplifier operation, so the transfer and reflection characteristics are tested in 880MHz.

TABLE I. THE GDA UNIT MEASUREMENT RESULTS

G.D.[ns] @880MHz	S21[dB] @880MHz	S11[dB] Max.
1.004	-0.8	-18.0
1.202	-0.9	-17.4
1.401	-1.0	-16.7
1.603	-1.1	-15.9
1.801	-1.3	-15.1
2.005	-1.8	-13.2

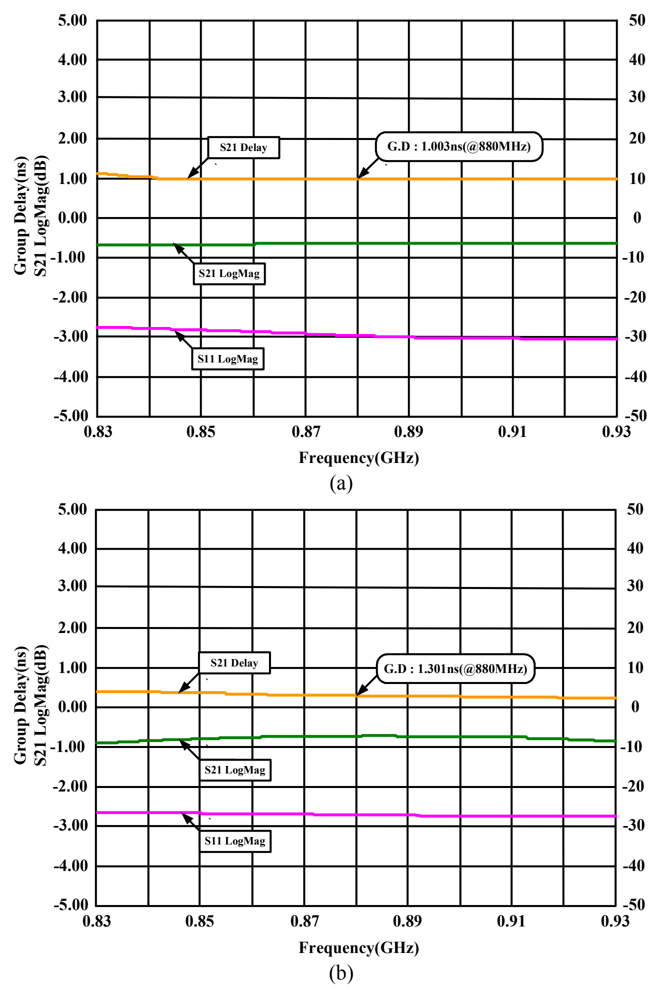
The measurement results are shown in Table I. A variation of group delay is about 1ns to 2ns. A reflection coefficient of the GDA unit is under –18dB overall.

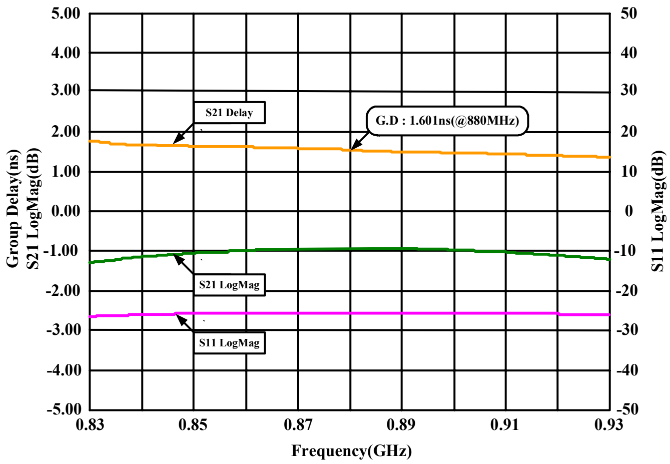
D. A transmission type GDA

In order to obtain better reflection characteristics of the GDA, a transmission type GDA is proposed and shown in the Fig. 6. Actively, it is confirmed that the reflection coefficient of the proposed transmission type is better characteristics than the single GDA unit in the in-band.

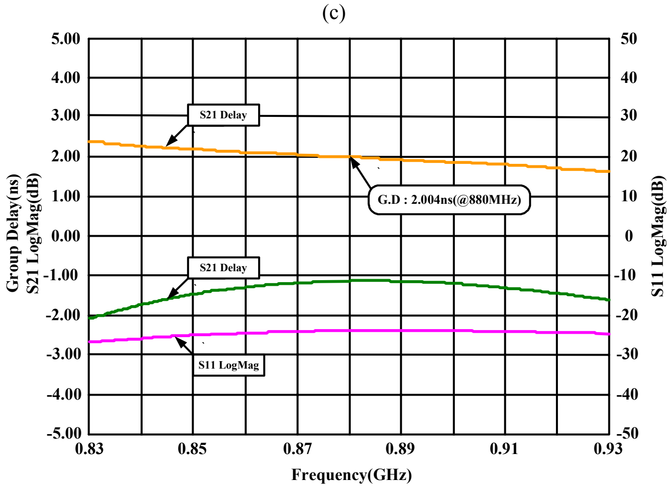
The fabricated GDA is tested on cellular band (869-894MHz). When the minimum group delay time of the GDA is 1.003ns, the transfer characteristics and the maximum return loss are –0.580 ±0.006dB and –29.13dB, respectively. When the maximum group delay time of GDA is 2.004ns, the transfer characteristics and the maximum return loss are –1.140 ±0.040dB and –23.74dB, respectively.

Although we could obtain more the group delay time variance, the transfer characteristic flatness is so bad that we have no choice but to accept a variation range of group delay time as 1ns. Fig. 7 is shown the measured electrical characteristics of the fabricated GDA.





(c)



(d)

Fig. 7. The electrical characteristics of the fabricated GDA.
(a) *G.D.* = 1.003ns @880MHz (b) *G.D.* = 1.301ns @880MHz
(c) *G.D.* = 1.601ns @880MHz (d) *G.D.* = 2.004ns @880MHz

IV. Conclusion

We designed the GDA that is able to adjust the group delay time using the resonance circuit with a variable capacitance and a variable virtual inductance. We obtained the better reflection characteristics, as the transmission type GDA is proposed. The GDA will go far toward improving in quality in more complex wireless communication system. The interference signal in the wireless communication system is changed by environment. The conventional interference cancellation system cancels out the interferences with a constant condition, but the interference cancellation using the GDA is more effective because it can make correction signal that correspond to a variable delay time of the interference signal. It will be possible to cancel the interference signal for the GDA when it is used with amplitude and phase adjuster. If we apply the GDA to the wireless repeater system using a co-channel interference cancellation technique and a feedforward circuits for a good linearity, we feel confident that the GDA contribute not only improvement in a quality of communication, but also in a fabrication of communication system.

References

[1] S.J.Kim, J.Y.Lee, and J.C.Lee, "Adaptive feedback interference cancellation system (AF-ICS)," *IEEE MTT-S Digest,* pp.627-630, 2003.

[2] Yong-Chae Jeong, "A feedforward power amplifier with loops to reduce Rx band noise and intermodulation distortion," *Microwave Journal,* vol.45, no.1, pp.80-91, Jan. 2002.

[3] Inder Bahl, Prakash Bhartia, *Microwave Solid Circuit Design*, pp.626-659, John Wiley & Sons, 1988.

[4] David M. Pozar, *Microwave engineering*, Second Edition, John Wiley & Sons, N.Y., 1998.