Avoidance of Off-switch Resonance in True Time Delay Line using Cascaded Switches

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***Abstract*—In this paper, we propose the design of switched line True time delay (TTD) using cascaded switches, which removes off-switch resonance. Conventional switched lines with two different delay-time difference, 15ps and 270p, are presented to indicate that off-switch resonances can be observed in switched lines using switches with a fair isolation of 15dB. Switched line with cascaded switches is designed and fabricated to show the resonance can be eliminated. All designs are conducted in consideration of matching. The measured results are in agreement with the simulation results in CST Design Studio.**

Keywords—cascaded switches, isolation, resonance, true time delay, wideband.

I. INTRODUCTION

Phased array antennas are widely used in radar and wireless communication systems [1]. One trend in radar and wireless communication systems is the increasing bandwidth requirements [2]. Phased array antenna system with phase shifter is operated in narrowband. True time delay line is required for beam steering in wideband antenna system. TTD lines are most easily realized as switched line configuration. To achieve advanced TTDs high quality switches are required such as PIN diode switches [3]. However, PIN diode switches have larger loss and need more current than integrated circuit (IC) switches. IC switches have many advantages which are small size, simple control, fast switching speed, etc. Nevertheless, SPDT IC switches have fair isolation characteristic for low insertion loss. Because all lines should be separated sufficiently without the off-state capacitor resonance in each delay state, high isolation characteristic of switches is required [3]. This paper shows that design using cascaded switches topology to enhance isolation characteristic, which remove the off-state capacitor resonance.

II. DESIGN OF TRUE TIME DELAY LINE

Fig. 1 shows conventional switched line with single pole double throw (SPDT) switches which can generate resonance if isolation characteristic of switches is around 15dB which is fair value of isolation. Long path line can be

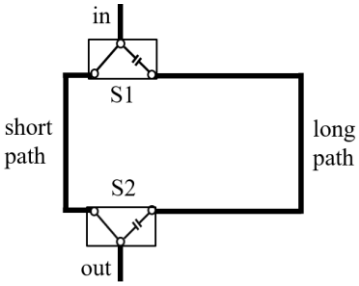

Fig. 1. Conventional switched line.

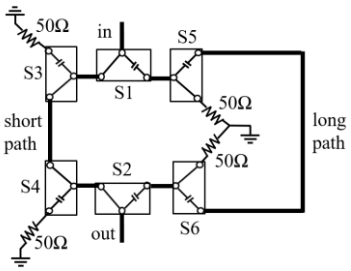

Fig. 2. Proposed switched line using cascaded switches.

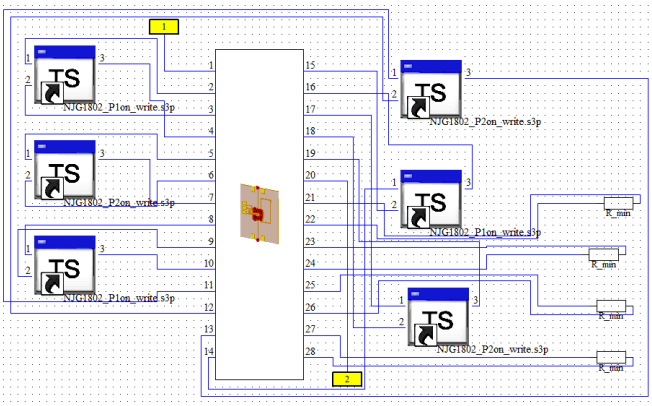

Fig. 3. Block diagram of proposed switched line using cascaded switches (CST design studio).

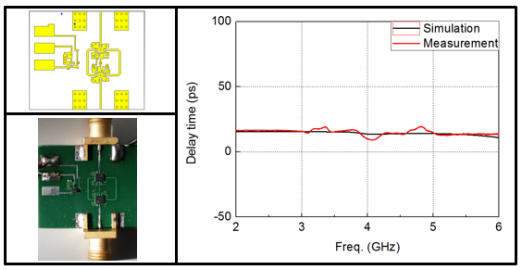

Fig. 4. CST model, fabrication model and simulation & measurement results of conventional switched line with 2 switches (Delay time difference: 15ps).

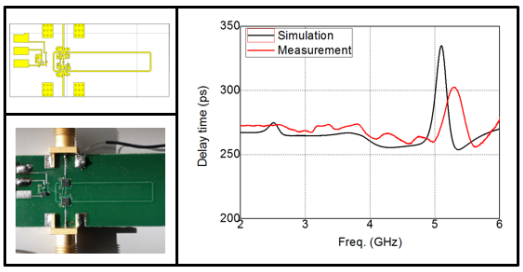

Fig. 5. CST model, fabrication model and simulation & measurement results of conventional switched line with 2 switches (Delay time difference: 270ps).

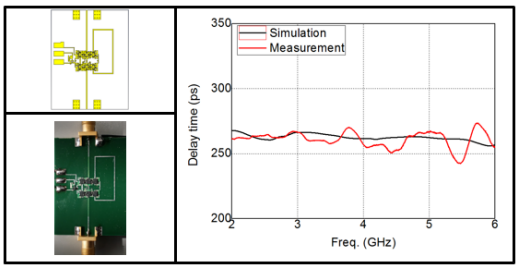

Fig. 6. CST model, fabrication model and simulation & measurement results of proposed switched line using cascaded switches with 6 switches (Delay time difference: 270ps).

seen as parallel resonator by capacitive coupling through off-switch capacitor. The signal passed through off-switch capacitor has very small magnitude but it becomes the cause of resonance and affects phase characteristic between input and output, so that group delay can be distorted. The resonance occurs when electrical length of line is N·λ/2 where N is a positive integer.

In this work, switched line using cascaded switches in Fig. 2 is proposed to solve the problem. Two off-switch capacitors are placed before long path line so that isolation of circuit is improved. On state termination of added switch (S3, S4, S5, S6) has been selected 50 Ohm for matching.

Because group delay variation can be generated by the reflected waves due to discontinuity and impedance mismatch, matching is important consideration in design of delay lines [4]. Characteristic impedance can be controlled by changing width of the lines for compensation of on-switch series resistance of several ohms, which is able to achieve matching of the total circuit.

III. Simulation Results

Simulation has been done in CST Design Studio (DS) in Fig. 3. DS simulation is EM circuit Co-simulation tool. After EM simulation, total circuit simulation with S parameter measurement (S3P) of SPDT switches is conducted for accurate result with fast time.

First, conventional switched lines with 2 switches are designed and fabricated with two different delay time difference, 15ps and 270ps in Fig. 4 and Fig. 5 respectively to look into the off-switch capacitor resonance. We use SPDT switches, NJG1802K51 of New Japan Radio Company which have fare isolation of 16dB at 6 GHz. Long path line of a model with delay time difference of 15ps in Fig. 4 is shorter than half wave length at 6 GHz. Because the range of the S parameter measurement (S3P) of SPDT switches is up to 6 GHz, resonance is not observed in Fig. 4. On the other hand, resonance can be observed at around 5 GHz in case of a model with delay time difference of 270ps in Fig. 5.

Proposed switched line using cascaded switches with 6 switches are designed and fabricated with delay time difference of 270ps in Fig. 6. Compared with conventional model, resonance is effectively removed. The graphs shows that the measurement results are in agreement with the simulation results.

IV. Conclusion

Conventional TTDs and TTD using cascaded switches have been fabricated and measured to compare with CST DS simulation results. Simulation and measurement result have demonstrated that the switched line using switches with fair isolation of 15dB can generate the off-switch capacitive-coupled parallel-resonance whereas TTD with enhanced isolation using cascaded switches can remove the resonance.

Acknowledgment

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