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Crosstalk Noise Reduction Using Synthesized Digital Logic Circuit

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***Abstract*—This work involves crosstalk reduction using synthesized digital logic circuit. Crosstalk noise is an unwanted coupling between two different signal paths. Capacitive and inductive crosstalk has become a major concern in the design of high-performance large scale integration digital circuits. A fundamental requirement for interactive broadband service was adequate reduction in crosstalk noise signals. One attractive solution was the use of SDLC design technology in realization of the access networks via standard copper telephone lines and noise reduction. The results of the analysis in this work showed that an increase in the loop length between the two wires resulted in decreased coupling. Furthermore noise voltage was 0 volts when either the timing of the aggressor or the timing of the victim net was 0 volts; thereby reducing crosstalk noise. Also, the noise voltage was at a minimum leading to reduced crosstalk and improved quality of service for Nigeria's telecommunication industry.**

Keywords—crosstalk; aggressor*; victim; noise; SDLC*

I. INTRODUCTION

Crosstalk is signal overflow from two adjacent wires. It is an unwanted coupling between two different signal paths. Excessive crosstalk can cause circuit false triggering; even the system to work incorrectly. The major offender of single cable operation is near-end crosstalk (NEXT) and when the two directions of transmission are carried in separate cables or use shielded pairs in a common cable, far-end crosstalk (FEXT) becomes dominant [1].

NEXT is the signal travelling in the opposite direction to the aggressor (the dominant of the two signals). It propagates in the reverse direction of the aggressor signal edge and has width that is twice the signal propagation time. Its amplitude is determined by coupling; it saturates when the parallelism length is equal to the aggressor edge length. It has a positive coupling caused by mutual inductance and capacitance. NEXT is the sum of the crosstalk signals that travels in opposite direction to the interfering signal. FEXT is the signal travelling in the direction aggressor signal. It propagates with the aggressor signal edge and has same width as aggressor signal edge. The pulse energy generated in FEXT grows continuously and has negative coupling caused by mutual inductance and positive coupling resulting from mutual capacitance. FEXT is the sum of crosstalk signal traveling in the same direction as the interfering signal and the interfered receiver is in far end. It occurs at far end receiver as a result of adjacent channel signals travelling in the same direction.

Good communication systems should provide sufficiently strong signals at the receiver to overcome all forms of interference, while simultaneously ensuring that the received signal is free from any form of distortion and fading [1-2]. These goals are, however difficult to achieve in wireless mobile channel circuit. This is because, unlike the fixed channel, the wireless channels or mobile system usually encounter fading which normally yields in the fluctuation of signal to Noise Ratio (SNR) and will further result in poor voice quality, severe signal degradation and service interruptions, slow link speed and dropped calls [3]. High humidity and wet weather conditions can result in increased electrical crosstalk over a telephone system [4]. Despite being relatively continuous, crosstalk can be reduced with proper precautions and hardware. Capacitance imbalance between wire pairs has been found to be a major contributor to poor crosstalk coupling loss [2]. Stringent quality control during cable manufacture is form of mitigation to ensuring minimum balance values.

Crosstalk noise violations could be resolved by identification of victim and aggressor wire spacing, shield insertion (i.e. shielding and coating of aggressors and victims independently), incremental re-routing, repeater insertion, upsizing and downsizing of victims and aggressor respectively, and filtering static nets [5]. In his work, appropriate adjustment of wire spacing between victim and aggressor was adopted.

II. RESEARCH METHODOLOGY

Crosstalk reduction can be achieved by several circuit techniques such as dogleg channel router, high speed circuit design, very large scale integration (VLSI) routing using particle swarm optimization (PSO) techniques, very high speed digital subscriber line, crosstalk minimization method for system on chip, Optic fibre VLSI circuit simulator etc. Of all these, synthesized digital logic circuit (SDLC), offers the best trade-off. These include accuracy, flexibility, speed, reliability, effective timing analysis and cost.

SDLC design is a pre-layout design mechanism with buffers, repeaters and up-converter to increase the frequency from the low state to high state in digital signal. Also, it helps in the logic synthesizing of the processes so data and signals can behave abstractly to suite the circuit design automation [6-7]. Furthermore, SDLC design employs a method that prevents and predicts crosstalk occurrence by simulation and synthesizing the results to effectively optimize the signal path against any form of noise; hence ensures reduced peak noise voltage with standard tools. This is in contrast to unconstrained synthesis, which attempts to use weak drivers whenever possible. These unconstrained synthesizers only consider timing and the area while ignoring noise effects. SDLC design provides the possibility of improving on the reliability and maintainability of the circuit in order to minimize noise effectively on the basis of gaining communicating signals operation, and therefore boosting the quality of signal service and signal integrity [7]. The SDLC facility used in this research work for data synthesis was provided by Globacom Nigeria, one of the major global systems for mobile communication (GSM) network providers in Nigeria and the country’s second national carrier with trans-Atlantic fibre optic data connection.

To solve electromagnetic problems such as crosstalk noise and congestion, interconnect modelling can be used in SDLC. The interconnect method was formulated by modifying Maxwell’s curl equation to give solution for electric and magnetic fields. It estimates amplitude voltage of NEXT crosstalk noise Va, which is computed using (1):

$$V_a = {}^{V_{input}}/_{4l} * \left\{\frac{L_m}{L} + \frac{C_m}{C}\right\} X_a * X_v \qquad (1)$$

Where $Vinput$ is the amplitude of drive signal, Lm is the inductance coupling of the two adjacent trace and Cm is the capacitance coupling, while L and C are the distribute parameters.

The forward crosstalk noise Vb can be calculated as given in (2)

$$V_a = V_{input} * X_a * X_v * \frac{\sqrt{LC}}{2l}\left\{\frac{C_m}{C} - \frac{L_m}{L}\right\} \qquad (2)$$

Where Xa and Xv are the data transfer rate (mbps) of the aggressor and victim and l represents the loop length. Vb is the estimated amplitude voltage of the FEXT crosstalk noise as in (2). Shown in Fig. 1 is the plot of the relationship between coupling capacitance and signal-carrying wire spacing. The increase in the coupling capacitance of the adjacent wire pair is inversely proportional to the spacing between them with a correlation factor of 0.98.

Fig. 2 shows the block diagram of a conventional SDLC design [8]. A signal detector is used to detect a signal a transmitted across the transmission channel. It also recovers required information contained in a modulated wave [9]. Intermediate frequency (IF) amplifiers are incorporated in SDLC design to filter and reject unwanted signals. An up-converter is used to convert a band of frequencies from a lower frequency to a higher frequency. The low noise down-converter receives the signals from the transmitter base station, amplifies it, and down-converts the block of carrier frequencies to a lower block of IF. It also reduces hums and ripples in the signal reaching the receiver [10].

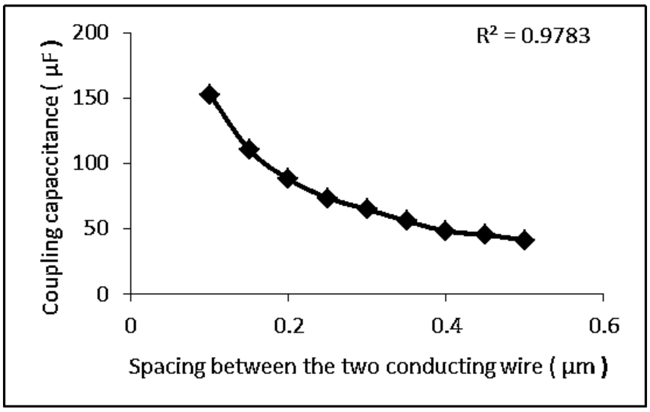


Fig. 1 *Coupling capacitance against spacing between adjacent wires*

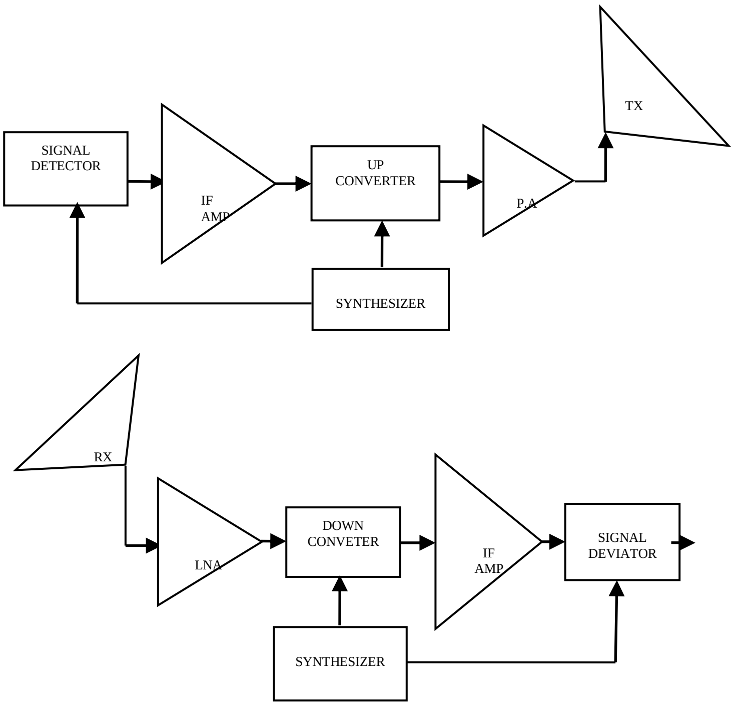
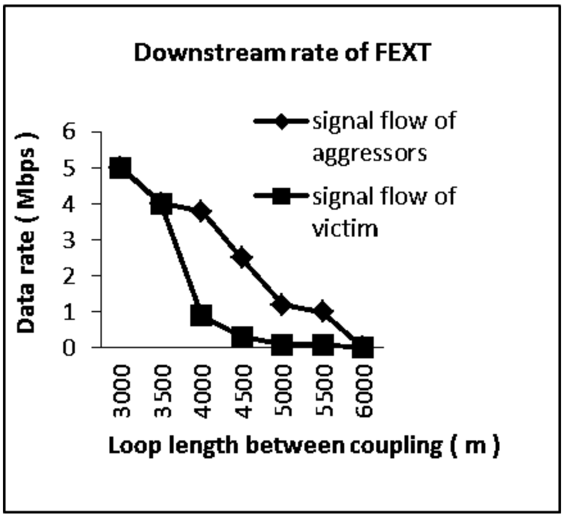


Fig. 2 *Block diagram of SDLC design with embedded components [8]*

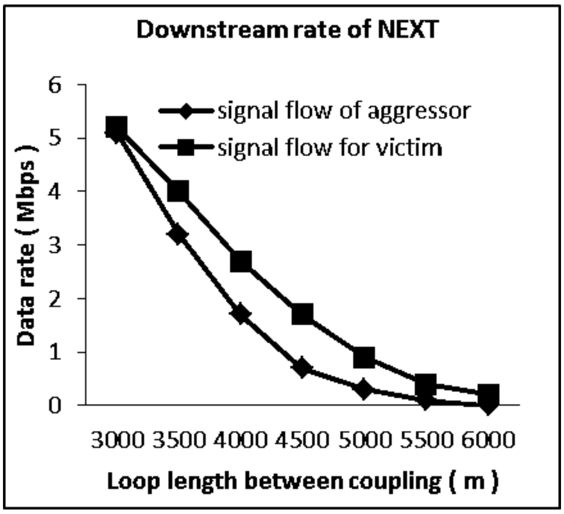
Power amplifiers (PAs) are electronic amplifiers that amplifies low-power, audio signals to a level suitable for driving loudspeaker in mobile phones. A synthesizer is a stable frequency source with variable discrete outputs that generates electric signal oscillations with accurate timing via the use of clock. The Low Noise Amplifier (LNA) reduces losses in the feed line; it is also used to amplify very weak signals [9]. Signal deviators are placed in the receive end to deviate the signal detected by the signal detector to receivers. Deviation is the amount of frequency swing above and below the transmitter carrier frequency when the modulating voltage is applied to the low level radio frequency (RF) energy to enhance communication between both ends [10-11].

The downstream data rates for FEXT and NEXT noise are displayed in Figs. 3 (a) and (b) respectively. For the FEXT, the aggressor exhibits higher downstream data transfer rates than the victim for $3500m \le l \le 6000m$ while both the aggressor and victim experience the same transfer rates for $6000m < l < 3500m$. In the case of NEXT, the victim shows higher downstream transfer rate all through except for $l = 3000m$ and $l = 6000m$.



(a)

Shown in Fig. 4 is plot for total crosstalk occurrence for one of the major global systems for mobile communication (GSM) network providers in Nigeria. The data from Nigeria Communications Commision (NCC) [12] comprises crosstalk variations for 36 sites over a span of seven years (2008-2014.)



(b)

Fig. 3 *Downstream rate for (a) FEXT and (b) NEXT*

While significant reduction in crosstalk was realized in the year 2014 in some states such as Enugu, Ebonyi, Kaduna, Kebbi, Kwara, Lagos, Osun, Ondo, Ogun and Plateau states, others states experienced increased crosstalk occurrences. This accentuates the necessity for deliberate and concerted efforts to further expand research frontiers in eliminating crosstalk menace in voice communication across various telecommunication networks.

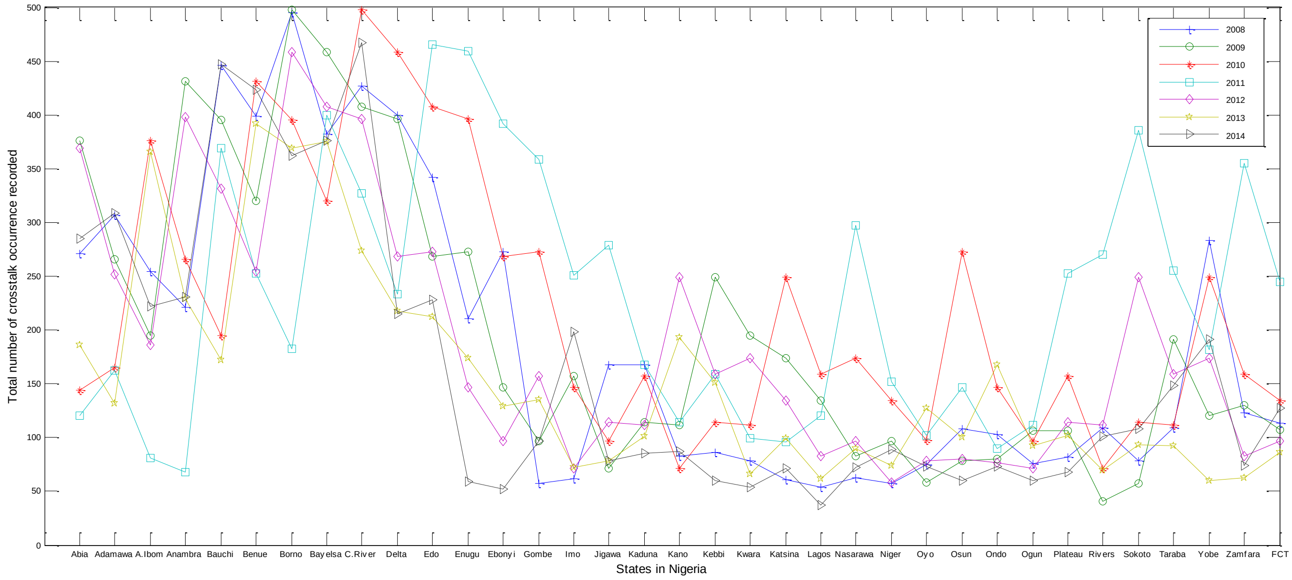
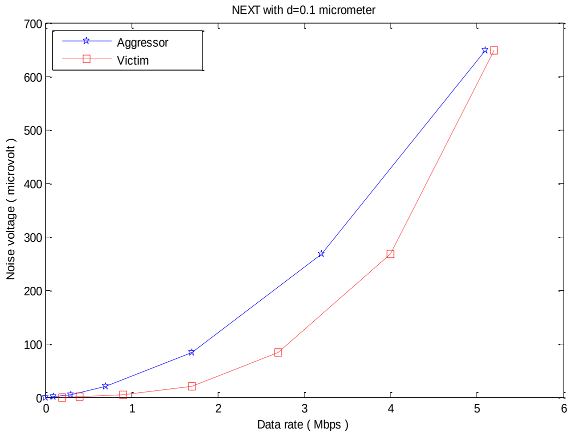


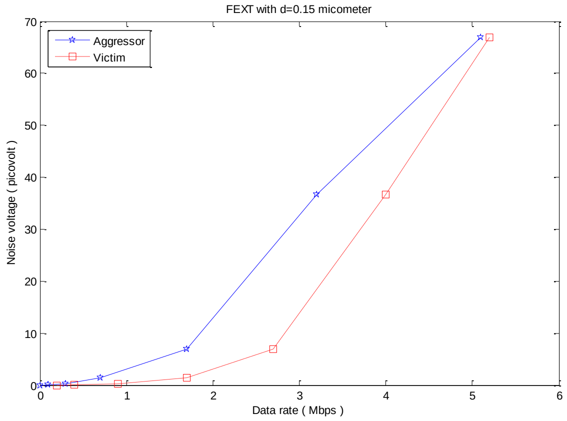
Fig. 4 *Total occurrences of crosstalk noise as recorded by Globacom for 36 stations in Nigeria for 2008 to 2014*

III. RESULTS AND ANALYSIS

Observations from results of network measurement made shows that with meticulous variation of aggressor and victim spacing, it is quite possible to reduce crosstalk noise. Fig. 5 (a) is a plot showing the effect of using 0.1 µm spacing in a NEXT induced circuit, while the plot for FEXT with 0.15 µm spacing is displayed in Fig. 5 (b).However, for both the crosstalk voltage noise increases with increased data transfer rate; with the victim at higher data speed than the aggressor.



(a)



(b)

Fig.5 *NEXT with 0.1 µm spacing and (b) FEXT with 0.15 µm*

Measured crosstalk noise voltage noise voltage at various spacing with different signal data rates for both NEXT and FEXT induced circuits are given in Table I.

The noise voltage of the NEXT signal 1 at d=0.2 μm in Table I is 108.031 μv; hence the noise voltage is capable of creating crosstalk noise between the trace. It was observed that at spacing $d < 0.18\mu$m substrate technology, the noise voltage is greater while at $d > 0.18\mu$m, the noise voltage is reduced. Hence, the noise voltage is inversely proportional to the spacing between the trace. The noise voltage of the FEXT signal 5 is 0.1349 pV, and the voltage of the noise is capable creating crosstalk noise between the signal traces.

Fig. 6 is the standard and proposed flow for year 2014. To iteratively carry out crosstalk analysis, setup violation and the hold violation are considered. Setup and hold violations are closely related, and often, fixing setup violations would make the number of hold violations increase and vice versa.

TABLE I. *NOISE VOLTAGE FOR NEXT AND FEXT AT VARIOUS SPACING WITH DIFFERENT SIGNAL DATA RATES*

Parameters			**NEXT**			**FEXT**	
Signals	**Aggressor** (Xa) (mbps)	**Victim** (Xv) (mbps)	**Noise voltage @ d=0.2 μm** (µV)	**Noise voltage @ d=0.5 μm** (µV)	**Noise voltage @ d=0.1 μm** (µV)	**Noise voltage @ d=0.4 μm** (pV)	**Noise voltage @ d=0.15 μm** (pV)
Signal 1	5.1	5.2	108.030	9.742	648.4	4.680	66.971
Signal 2	3.2	4	44.731	4.030	268.266	2.567	36.740
Signal 3	1.7	2.7	14.030	1.265	84.178	0.493	6.871
Signal 4	0.7	1.7	3.234	0.291	19.398	0.094	1.339
Signal 5	0.3	0.9	0.661	0.060	3.961	0.013	0.193
Signal 6	0.1	0.4	0.089	0.009	0.534	0.010	0.146
Signal 7	0	0.2	0.000	0.000	0.000	0.000	0.000

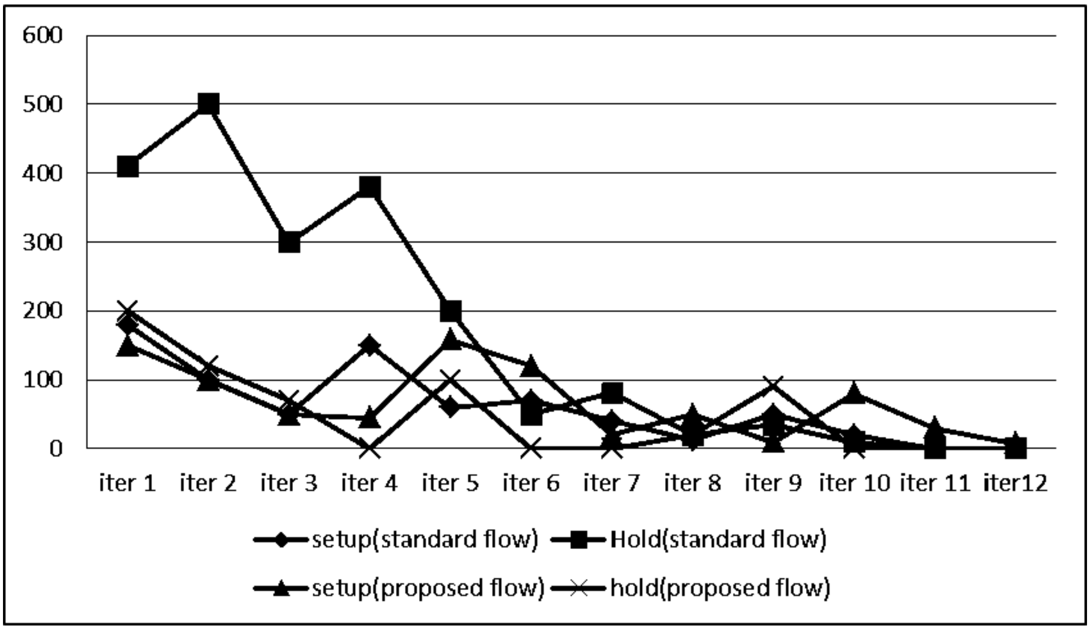


Fig. 6 *Plot of standard and proposed flow for year 2014*

From Fig. 6, the standard and proposed flow for crosstalk violations utilized 12 timing closure iterations, and these long iterations was to intended to obtain a zero value for both the hold and setup violations as evidenced in iterations 11 and 12. This implies that there is no violation, thereby leading to reduction in the effect of capacitive coupling on the design.

IV. CONCLUSIONS

This paper investigated the reduction of crosstalk noise using synthesized digital logic circuit. It is necessary to improve the quality of service and reduce cost to customers. It is also important to ensure that service level agreements are guaranteed, which will manifest in reduced crosstalk. Furthermore, it was observed that increased loop lengths of two or more signals resulted in reduced coupling between the signals trace which consequently resulted in reduced crosstalk.

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