Correction to the July 2008 issue

We made a layout mistake in the article, "Software Enhances the Design and Analysis of Tunable Circuits," by Dale Henkes. Two pages were reversed, so the print and online editions of *High Frequency Electronics*, the article should read as pages 54, 56, 58, 57, 60. The error will be corrected for the version of the article placed in our online Archives.

Our sincere apologies to the author, and to any readers who were confused.

A Few High Speed Design Notes

High speed digital design has both similarities and differences with RF/microwave design. Both rely on knowledge of frequency dependent effects, coupling and radiation, and transmission line behavior. However, the types of signals have fundamental differences. The most significant difference is waveform shape.

Bandwidth

RF/microwave designers mainly use the fundamental frequency only, and harmonics are considered distortion. Thus, the operating frequency and the maximum frequency are essentially the same. Bandwidths of an octave are considered extremely broadband.

On the other hand, a digital signal approximates a square wave, which must contain significant harmonic content to be considered a viable waveform. Thus, digital circuits must be able to handle multi-octave instantaneous bandwidth to pass the fundamental clock frequency and enough of the 3rd (and probably 5th) harmonic to maintain good wave shape.

Amplitude Distortion

Ideal digital signals are simply "on/off" with fast switching time. Small increments in amplitude are unimportant unless they become large enough to make the transitions ambiguous (e.g. close the eye on an eye diagram). Amplitude variations due to losses, frequency response and even crosstalk, are unimportant if they are simply maintained below the necessary threshold.

RF/microwave signals are quite different. The information they carry is modulated onto the fundamental frequency signal. Unless the modulation format has no amplitude components (e.g. FM or PM types), the linearity of the system is extremely important.

Phase (Time) Distortion

Certainly, we understand that variations in phase can have an effect on all but very narrowband signals. In RF/microwave design, we carefully consider phase shift, group delay and other related performance factors. We even use controlled phase shifts as part of the functional circuits, in modulation, splitting/combining, and antenna beamforming.

Phase/time variations in digital circuits have quite different effects, but are no less important. In fact, the variation in phase shift of the clock and its harmonics over a simple PCB trace can cause data errors. Another related matter is synchronization of clock signals across physical distances that represent a significant fraction of a wavelength at the clock frequency.

New Issues in High Speed Design

As noted in the this issue's tutorial article on EDA tools for high speed design, GHz-range clock speeds have moved high speed design from the "RF" range into "microwaves." This means that many of the relatively simple corrections for frequency-dependent effects are no longer sufficient to maintain reliable performance.

This means that high speed circuits rely more and more on electromagnetic analysis, based on core physical principles rather than equations that only approximate those behaviors. A few of the new issues to be dealt with at GHz clock speeds include:

- Greater differences in loss between the clock and its harmonic frequencies
- Increased crosstalk for the same PCB trace lengths
- Greater radiation, resulting in more difficult EMC compliance
- Lengths of board-to-board connectors, PCB traces, and even wire bonds have much greater effect on integrity of the digital signal
- Simply scaling circuits to smaller dimensions (e.g., proportional to wavelength) cannot be fully accomplished, requiring more attention to the circuitry that interconnects active devices
- Power consumption tends to increase with frequency, so low power techniques and improved thermal management are needed to handle the higher amount of heat per unit volume
- More complex simulations when EM analysis is required, with longer computation times