Manage EMI from high-speed digital interfaces

Earl McCune & Peter Lefkin - January 17, 2014

Data rates used in today’s high-speed digital interfaces exceed many of the operating frequencies used in mobile communication devices, such as smartphones and tablet computers. Careful design is needed in the interface to manage the local electromagnetic radiation from the interface so that interference with any and all local radios is avoided. The most important techniques for managing EMI from high-speed digital interfaces are discussed, showing how each contributes to solving EMI issues.

The small size and low cost of high-speed serial (HSS) interfaces are particularly valuable for mobile devices that must be small, low power, and lightweight. Electromagnetic interference (EMI) problems arise when the mobile device must communicate with remote networks, because the data rates used in modern HSS interfaces often exceed the wireless communication frequencies used in the mobile radios.

To have successful mobile communication products, it is essential that all components within these products coexist while performing their tasks. This means not only that whatever radio signals that are generated unintentionally must not interfere with any intentional radio signals, but it also means that any intentional radio signals must not interfere with the operation of any other circuits. This is called the principle of mutual transparency. The operation of any circuit is transparent – meaning not interfering – to the operation of any other circuit. It is essential that specification development committees pay particular attention to EMI both from the interface into the radios, and from the radios into the interface, because any interface that is either vulnerable or noisy will not provide functioning products however well it might work on its own. MIPI® Alliance has developed two specifications that pay very close attention to mutual transparency.

Whenever electrons are moved around, electromagnetic science tells us (from Maxwell’s Equations) that radio signals will always be generated. Seven major techniques are available to manage EMI at design time. These techniques are isolation, signal amplitude, skew limits, data rate, signal balance, slew rate control, and waveform shaping. These techniques all have different effects, which are discussed in the following sections.

Isolation

Physical isolation is probably the most obvious technique. Once we have a radio signal, if we can keep it bottled up, then it will not bother anything. Isolation is never perfect though, and at cellular or wireless LAN frequencies, the practical isolation values vary between 20 to 40 dB. Achieving this level of isolation is usually essential to solving EMI problems. Therefore, careful measurement of isolation provided by IC packages and PCB layouts is extremely important.
Signal amplitude

Reducing the amplitude of the interface signal does lower EMI, but only very slowly. If the signal amplitude is cut in half, then the EMI drops by only 6 dB. This may be enough to get out of a close problem, but this approach also reduces the receiver margin and may lead to interface errors. It is best left as the last resort for these reasons.

Skew and balance

Skew is the time shift between the two components of a differential signal. Balance is the amplitude matching between the two components of a differential signal. These are largely set by the interface driver circuitry, and they are best analyzed together. As Figure 2 shows, when the signal balance is within 10%, its exact value really does not matter compared to the EMI impact from skew. This means that from an EMI point of view it is far more important to minimize skew than to be concerned with amplitude balance when designing interface driver circuits.
With a combination sweep of both signal balance and skew, this figure shows that managing skew is much more important than getting a very close signal balance. Even with a 2% UI skew, the effect of signal balance errors up to 10% become negligible. Signal balance becomes important only if the skew is exactly zero, an unlikely condition.

**Data rate**

The radio spectrum from a digital signal has distinct properties, and from an EMI perspective the most important one is the spectral null at the data rate and its integer multiples. These spectral nulls are clearly seen in Figure 3.
Figure 3 Changing the interface data rate moves the spectral null. This is a particularly effective technique to reduce EMI for a particular band without any need for filtering.

These nulls exist independent of any signal filtering. It is practical to change the data rate then to move a spectral null close to a radio receiver band to remove EMI into the receiver. This is particularly important for GPS receivers, which must work from extremely tiny signals from multiple satellites. Figure 3 shows this technique used to help protect a GPS receiver, changing the data rate from 1.248 Gbps (Fig 3a) to 1.456 Gbps (Fig 3b). Slew rate

Slew rate

All of the necessary information that the interface carries is in the main spectral lobe. Spectral sidelobes represent information about the data waveform transitions, not the data itself. For EMI that is caused from energy in these sidelobes, which are all at frequencies above the data rate, it is possible to suppress this interference by reducing the slew rate of each waveform transition. This works because the total bandwidth of the unintentional radio signal is not governed by the data rate, but instead by the fastest transition (edge) in the data waveform.
Figure 4 The effect of slew rate control on higher frequency sidelobes from a differential signal: top) definition of edge transition time on the eye diagram; bottom) corresponding spectra from the transitions shown in part a).

Figure 4a (top) illustrates that this technique does impact the ‘eye diagram’ of the interface signal. The separation of the eye top and bottom is not affected, though the width of the eye that is fully open is reduced. This is a necessary price for using this filtering technique.

Note that slew rate control only reduces magnitude of the sidelobes. Any effect on the main lobe is negligible. This is both good and bad. It is good because this means that slew rate control does not reduce the data content. It is bad only if the frequency of interference is coming from the mainlobe, because then this technique is ineffective. For this reason some applications, such as the MIPI Alliance DigRFISM application using M-PHY®, prefer to use multiple lanes of M-PHY each running at lower data rates than having one lane operating at a higher data rate.

**Waveform shaping**

The straightforward way to implement slew rate control is to adjust the current sources charging and discharging capacitors. This yields the straight-line transitions seen in Figure 3 and below in Figure 5a. Other waveform shapes do impact the EMI values, some for better and some for worse. For example, Figure 5b shows the effect of an exponential waveform resulting from simple R-C filtering. Here the EMI is actually worse. The reason is that the exponential waveform has a sharp corner when any transition starts, even though the finish of any transition is smooth. By then, the damage is done.
Figure 5 EMI signal spectral variations with different waveform shapes for the signal transitions: a) linear transitions, b) exponential transitions, and c) filtered waveform. Exponential transitions are actually the worst for EMI suppression.

Figure 5c shows that when all sharp corners are removed from the interface waveform, the spectral containment is greatly improved. Removing sharp corners is the primary objective of waveform shaping, which is sometimes referred to as waveform curvature limiting.

**Technique combinations**

All EMI management techniques begin with maximizing physical isolation. Adding to this isolation, different techniques are used depending on the particular issues encountered by the interface standardization committee. Two examples from published MIPI standards are presented below.
The MIPI Alliance M-PHY specification is a HSS link that uses low-amplitude differential signaling. Because the data rates are higher than many cellular and other wireless communication frequencies, a combination of data rate selection, slew rate control, and bounds on skew are used to reduce EMI present at the input of internal (including possibly monolithic) radio receivers. One example of the improvements seen is shown in Figure 6.

![Figure 6](image)

**Figure 6** The MIPI Alliance M-PHY interface combines slew rate control with skew bounds to manage EMI reduction at high frequencies. Compare this result with the spectra in Figure 4b.

The MIPI Alliance RF front end (RFFE) interface has different problems, and uses different techniques to manage EMI. The RFFE application requires single-ended signaling with large amplitude, even though this interface operates directly next to sensitive radio inputs. The technique combination adopted here is to first use the lowest data rate that is consistent with the application needs. Then, we use curvature control on the interface waveform to insure that any EMI is bounded below the local radio operating frequencies. One example of how this works is shown in Figure 7.
The MIPI Alliance RFFE interface combines data rate selection and waveform shaping to keep the unintentional radio signal band limited below the major wireless communication bands: (top) 26 MHz data rate already keeps most of the signal energy at low frequencies, while (bottom) adding a small amount of curvature at the beginning and end of each transition provides dramatic improvement in EMI suppression.

Summary
EMI management by design is a key component to achieving mutual transparency between interfaces and radios that are present in mobile devices. This capability is best managed by the specification committees that are defining the interfaces, such as MIPI Alliance.

Experience with the MIPI Alliance M-PHY and RFFE interfaces during specification deliberations emphasizing mutual transparency shows that there are both very effective and less effective techniques available for EMI mitigation. By far the most effective technique is good physical isolation. After that is bounding of allowable skew for differential signals, and avoiding R-C filtering that results in exponential interface waveforms. Using waveform-shaping techniques to reduce sharp corners in the interface waveform is particularly effective in minimizing EMI.

One technique that does not require filtering is selection of the data rate. Since EMI from a digital waveform has spectral nulls at the data rate and all integer multiples, placement of these nulls near frequency bands of concern is also very effective. Last, and definitely least, is lowering the amplitude of the interface waveform. This technique has a very weak EMI impact.

**About the Authors**

**Earl McCune**

Earl McCune received his Bachelors, Masters, and Doctorate degrees at UC Berkeley, Stanford, and UC Davis respectively. His experience in RF circuits, signals, systems, and EMI spans more than 40 years. Within this career he has founded two Silicon Valley startups, Digital RF Solutions in 1986, and Tropian in 1996 which was acquired by Panasonic 10 years later. He has contributed within MIPI on EMI issues since 2007. He is an author with Cambridge University Press, and is a IEEE Microwave Theory and Techniques Distinguished Microwave Lecturer.

**Peter Lefkin**

Since 2011, Peter Lefkin has served as the managing director and secretary of the MIPI Alliance, having returned to the role after leading the establishment of its operational support structure at its inception in 2004.

In his role, Peter is the senior staff executive responsible for all MIPI Alliance activities and operations from strategy development to implementation. The managing director serves by appointment of the MIPI Alliance Board of Directors.

Peter is employed at IEEE as the director of alliance services (IEEE Standards Association), and previously served in the roles of director of IEEE conformity assessment program (ICAP), marketing and business development executive (IEEE-ISTO), as well as COO and CFO of IEEE-ISTO. He also has held positions at Motorola, American National Standards Institute and the American Arbitration Association.

Peter earned a BA degree in economics and political science from Boston University. He also attended Columbia University’s Senior Executive Program (CSEP).

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- [DesignCon 2014 highlights EMC and EMI talks](#)