Analyzing RF Coexistence in a Mobile Handset

A typical smartphone handset can contain numerous different RF systems, including multi-band cellular antennas, Wi-Fi, Bluetooth, NFC and navigation systems such as GPS and GLONASS. All these systems need to be able to coexist without causing cosite interference. This application note shows how CST STUDIO SUITE® and Delcross EMIT can be used to investigate interference between antennas on a smartphone, and how potential mitigation strategies can be investigated using simulation.

Full-Wave Simulation

As an example, this application note will focus on just three common RF systems: the cellular transceiver, the Wi-Fi and the GPS. The first two systems both transmit and receive signals, while the GPS system is simply a receiver. The phone model is for demonstration purposes only and does not represent any real product.

The phone model (Figure 1) is created in CST STUDIO SUITE, a 3D EM simulation tool containing full-wave solvers. The model includes the antennas for the three systems of interest, and farfield monitors at key operating frequencies of the different systems. A simulation is then carried out using the time domain solver across the spectrum from 0 – 6 GHz. This simulation provides both the S-parameters (Figure 2), which illustrate the wideband coupling (isolation) between each antenna, and the farfield patterns, giving the pattern degradation caused by installing the antennas in the environment of the handset. GPU acceleration can be used to improve the performance of the simulation.

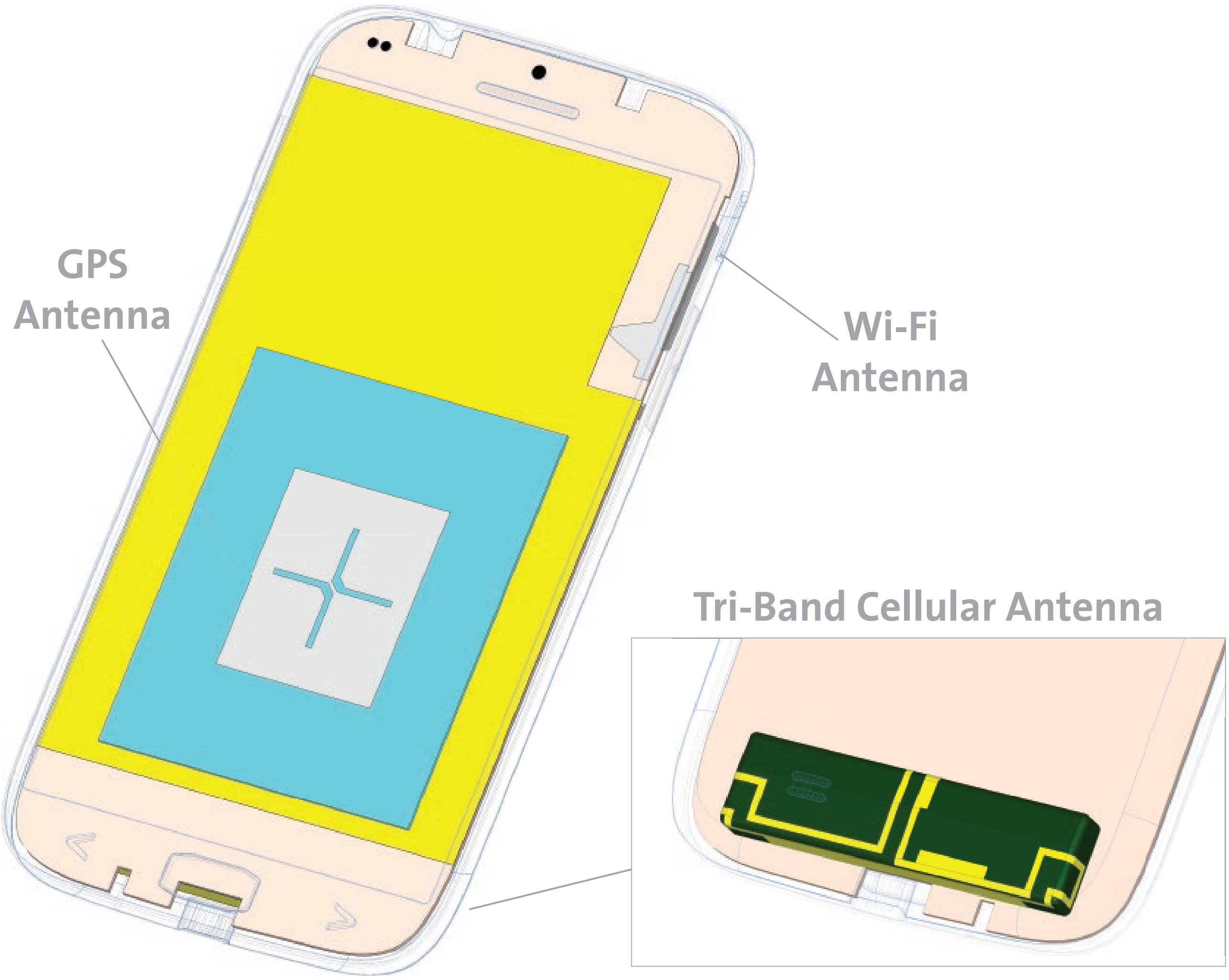

Figure 1: The antennas in the demo handset.

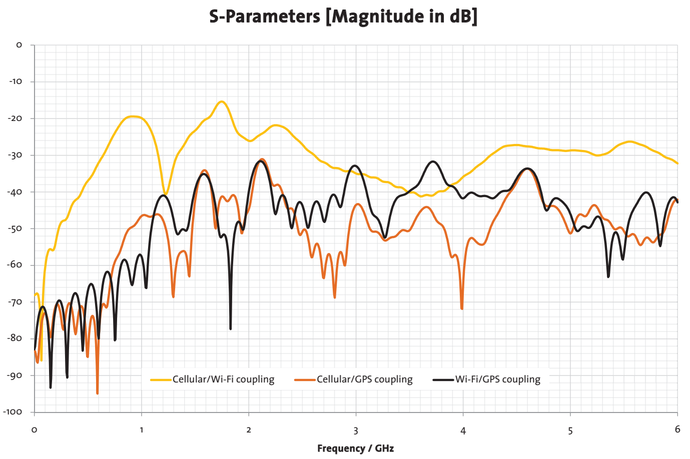

Figure 2: Calculated S-Parameters for coupling between antennas.

RF System Set-Up

Once all of the results have been calculated, the data can be transferred to EMIT using the "Export to EMIT" macro in CST STUDIO SUITE. This saves all of the S-parameters, the field patterns and the CAD data in a single directory, which can then simply be opened directly in EMIT.

After importing the files, the next stage is to define the RF systems themselves. EMIT includes a library of radios, power amplifiers, filters and other components, which can be assembled to produce a complete system. These models can include data such as channels, modulation and mixer products, as well as the programming of the radio. If a model is not available in the library, it is also possible to create custom models. In this example, the radios are set up as follows:

- The cellular system operates in both transmit (Tx) and receive (Rx) modes. It uses a *U-Blox* LISA radio, which includes the GSM-800, E-GSM-900 and PCS-1900 cellular bands, along with a *U-Blox* power amplifier (PA) on the Tx path.
- The Wi-Fi system also operates in Tx and Rx modes, and uses an LSR *TiWi* chipset model.
- The GPS system only operates in Rx and uses a generic GPS receiver model.

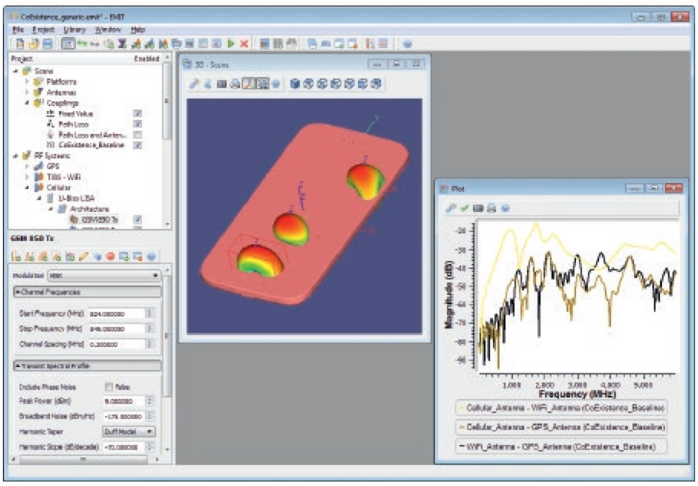

Figure 3: The project in EMIT, with the imported geometry, antenna patterns and wideband coupling data.

In this example, each system only uses one antenna. However, EMIT is also capable of modeling duplex systems which use different antennas for the Tx and Rx paths, and can calculate the self-interactions between a duplex system which is transmitting and receiving on different channels.

Cosite Analysis

With the RF systems defined, the potential for interference between the systems can be calculated. There are two scenarios that need to be considered when investigating cosite interference: the 1-on-1 scenario, where one system interferes directly with another, and the N-on-1 scenario, where multiple systems are transmitting simultaneously causing potential intermodulation problems.

1-on-1 analysis is much faster than N-on-1 analysis, since far fewer channel combinations need to be simulated. Because the N-on-1 analysis will include all potential 1-on-1 scenarios, it is a good idea to carry out the 1-on-1 analysis first, to identify and resolve these problems, before beginning the more time-consuming N-on-1 analysis.

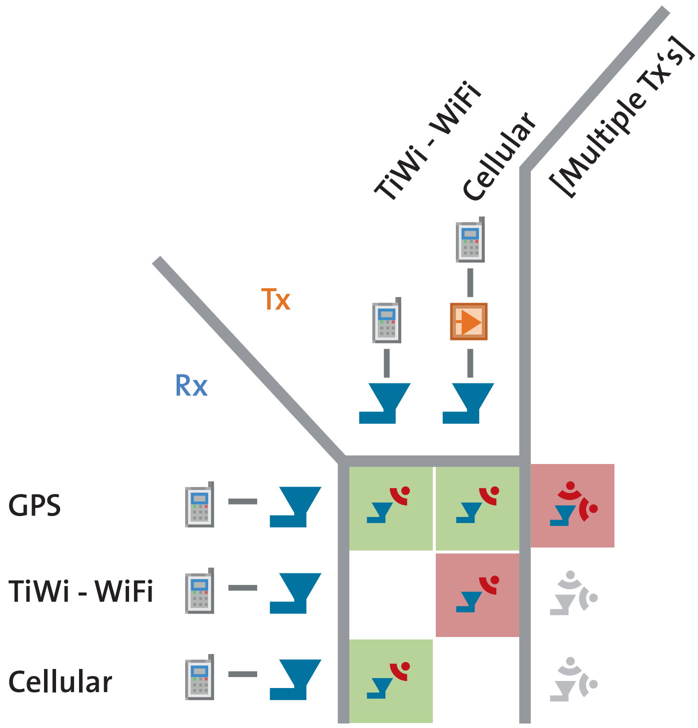

Figure 4: The threat matrix, including the results of both the 1-on-1 and N-on-1 simulation of the GPS system.

1-on-1 Analysis

After running the 1-on-1 simulation, EMIT produces a threat matrix (Figure 4) highlighting potential coexistence problems. Problem-free combinations are shown with a green square and combinations where interference issues have been identified are shown with a red square. In this case, there is interference to the Wi-Fi receiver when the cellular transmitter is operating.

Clicking on the affected square brings up the detailed results for this pairing, showing the maximum EMI for each channel. The interference problems fall clearly into two separate groups: the first three channels have EMI margins of around 48 dB, while the rest have EMI margins falling between 22 and 25 dB. This suggests that there are two separate phenomena at work.

For the first group, two peaks appear in the broadband (point) EMI margin (Figure 5). One peak occurs at the Rx frequency (in-band) and the other is out-of-band of the Rx frequency. These WiFi Rx channels have both in-band and out-of-band interference issues from the GSM-800/900 radios.

The out-of-band issues are caused by the GSM Tx fundamental falling into non-ideal spurious responses of the Rx. This interference can be mitigated with additional filtering at the Rx. The in-band issues meanwhile are due to GSM Tx harmonics and cannot be mitigated at the Rx. To combat these, a reduction of harmonic radiation is required. This can be done using a low-pass or bandpass filter at the Tx to reduce the harmonic levels.

Multiple peaks are also seen in the broadband (point) EMI margins for the second group of channels (Figure 6). However, both of these occur out-of-band. The out-of-band issues are caused by the Tx fundamentals from the GSM-800/900 and PCS-1900 radios with the Wi-Fi Rx spurs, and can be mitigated with additional filtering at the Rx.

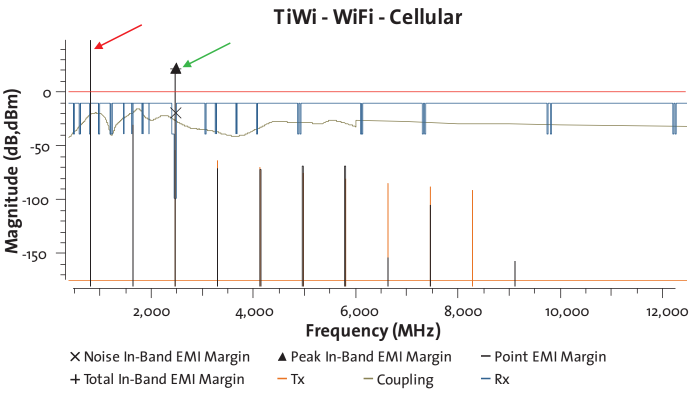

Figure 5: EMI at 2472 MHz. The red arrow shows out-of-band interference, and the green arrow shows in-band interference.

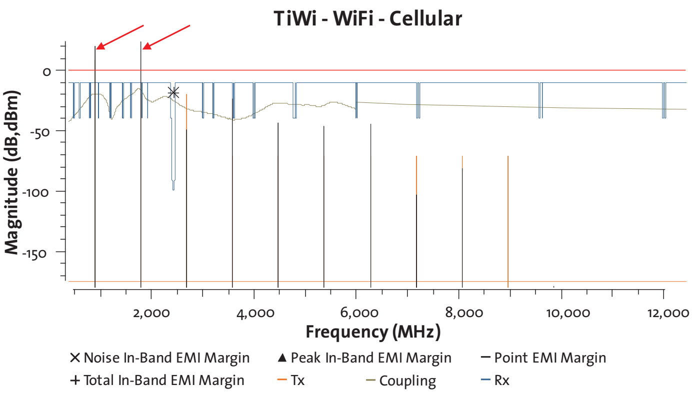

Figure 6: EMI at 2437 MHz. The root causes of interference for this channel are highlighted with arrows.

N-on-1 analysis

Once the 1-on-1 interference issues have been identified, the full N-on-1 analysis can be carried out. When simulating a multiple Tx scenario, EMIT calculates every possible combination of channels from every transmitter in the model operating simultaneously.

The threat matrix shows that the GPS system suffers from interference when the Wi-Fi and cellular radios are transmitting simultaneously, even though it does not experience interference from either one transmitting alone. This is indicative of an interference problem caused by intermodulation products (IMP).

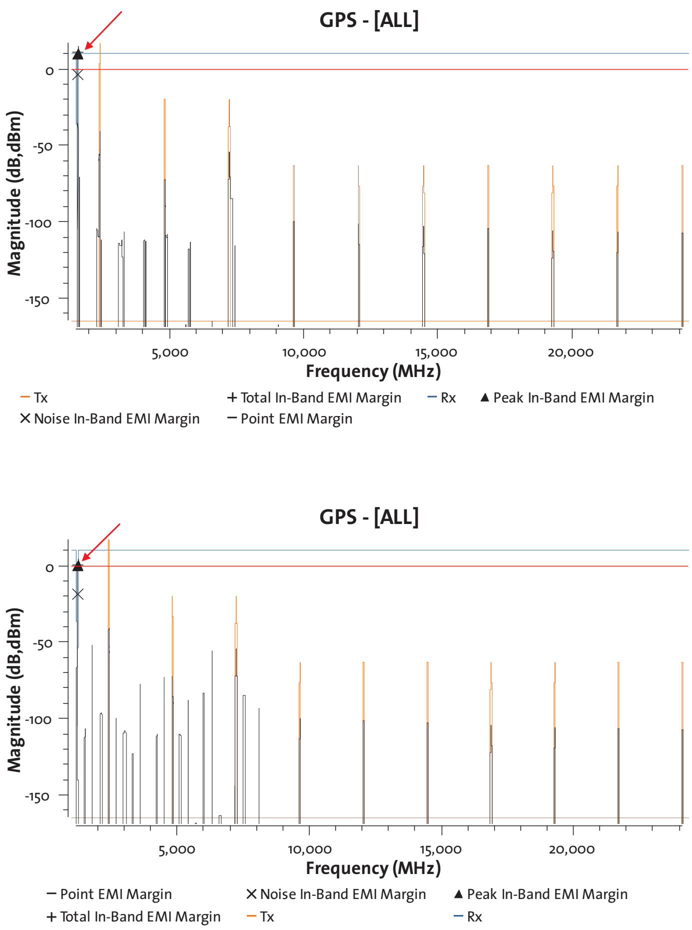

Figure 7: Interference due to intermodulation products in the L1 (top) and L2 (bottom) bands.

The results (Figure 7) show that both the L1 and L2 GPS frequencies experience interference. By computing the IMP produced by the Tx frequencies we find the culprits to be 2nd order IMP (L1) and 5th order IMP (L2). For example, in the L1 band, the Wi-Fi and GSM-850/900 Tx's generate 2nd order IMP at (2412 MHz - 849 MHz) = 1563 MHz, while in the L2 band, the Wi-Fi and GSM-900 Tx's generate 5th order IMP at (4*915 MHz - 2412 MHz) = 1248 MHz.

The power amplifier (PA) model is the only component in the model capable of generating intermodulation products. This means that the source of the interference comes from signals from the Wi-Fi Tx coupling into the cellular antenna, allowing the Wi-Fi and cellular signals to combine in the PA and producing intermodulation products that are subsequently re-radiated to the GPS antenna.

Mitigation measures

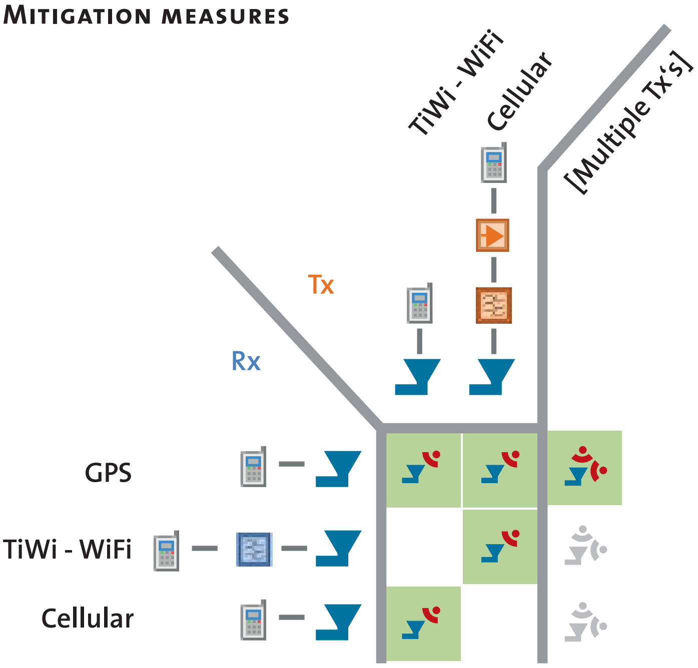

Figure 8: The threat matrix following the addition of filters.

To eliminate the intermodulation problems, we can add filtering to the cellular Tx to prevent the out-of-band Wi-Fi signals from reaching the PA. Using bandpass filtering will also reduce the harmonic emissions that cause interference at the Wi-Fi Rx.

In summary, two filters are needed to ensure peaceful coexistence: bandpass filtering at the Wi-Fi Rx to mitigate out-of-band interference, and harmonic filtering at the cellular Tx to mitigate in-band interference.

These filters are added to the model just like any other radio component. In this case, EMIT's built-in piecewise linear filter models have been used to approximate the response of generic filters. If the response of the actual filter model is known, this can also be used in the EMIT simulation by importing the Touchstone data file containing the filter response.

With the filters added, the simulation is re-run. The new threat matrix (Figure 8) is entirely green, indicating that coexistence has been achieved.

Conclusion

With so many RF systems included in handheld devices, it's important to ensure that they coexist peacefully. A coexistence analysis, using CST STUDIO STUDIO and EMIT, allows engineers to investigate the potential cosite interference problems that might arise in a design and to explore the various possible approaches for mitigating any interference effects that may arise.

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About EMIT

Delcross Technologies specializes in the development of commercial computational electromagnetic (CEM) and RF system analysis software products. Their EMIT simulation software predicts cosite interference between RF systems in complex electromagnetic environments. EMIT's unique multi-fidelity approach to predicting cosite interference provides rapid identification and "root-cause" analysis of EMI issues and provides a framework for rapidly exploring mitigation strategies.

EMIT is a product of Delcross Technologies, LLC and is distributed and supported worldwide by CST AG.
Further information on EMIT can be found at http://www.cst.com/emit.