TECHNICAL DOCUMENT

LARGE PLATFORM CO-SITE INTERFERENCE MITIGATION

Military aircraft, warships, armored vehicles, and other platforms contain numerous transmitting and receiving antennas. These serve a variety of electronic systems such as communication systems (including SATCOM), radar, positioning systems, and more. Even when operating on different frequencies, these antennas may interfere with each other due to their proximity.

Analyzing co-site interference using electromagnetics simulation solutions requires:

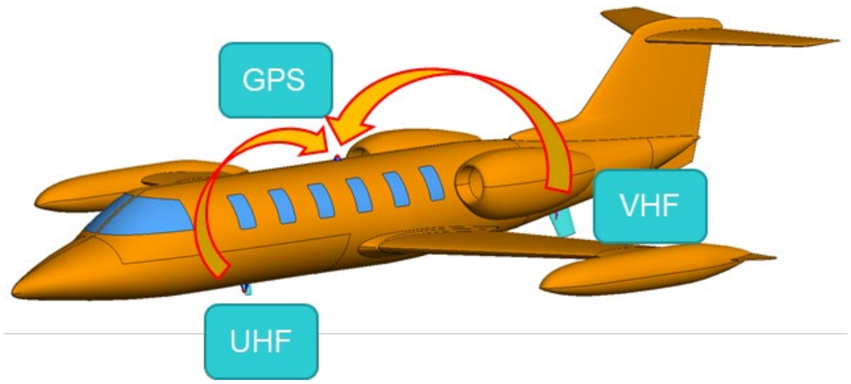
- Accurate determination of the coupling between antennas over a broad frequency range— even when platform geometries are complicated and no direct line of sight may exist
- Evaluation of the impact of non-linear electronic effects including harmonics, intermodulation, intermediate frequency breakthrough, image frequency, transmitter and receiver spectra, and receiver blocking

Collocation Interference

Even though ships, aircraft, army base camps, and similar platforms are considered "large," their antennas aren't very far apart. Because of these antennas' proximity, possible co-site interference between them is more than a matter of whether they're transmitting and receiving on the same (or adjacent) frequencies. Many other effects also need to be evaluated, including:

- Harmonics
- Intermodulation
- Intermediate frequency breakthrough
- Image frequency
- Transmitter spectrum
- Receiver selectivity
- Receiver blocking

All kinds of non-linearities of electronics play a role.



Example: UHF/VHF Antenna Interference with a GPS Receiver
In this illustration, we see an aircraft with two blade antennas on the underside of the fuselage, one for the Very High Frequency (VHF) band, and the other for the Ultra High Frequency (UHF) band.

On the top of the fuselage, the aircraft also has a GPS receiver antenna. The GPS receiver is highly sensitive because the signals from GPS satellites are weak.

So, even though the GPS receiver is listening on a different frequency than those on which the UHF and VHF antennas are transmitting, it may still suffer from the presence of those two transmitters, as some of their electromagnetic power will crawl around the aircraft's fuselage.

Altair's WRAP technology, part of the Altair® Feko® products, is designed to analyze and help engineers mitigate antenna collocation interference.

In the Collocation Interference Result window below, we can see three antennas listed and the interference count for each. For the GPS antenna, we see that it's affected by four interference components, two of co-channel/adjacent-channel interference, and two of harmonic interference.

Collocation Interference Result

File Edit View Settings Frequencies Calculate

Receiver	f [MHz]	B [kHz]	Max block [%]	Total	Co/Adj
Blade_VHF	131.2850	250	0.0	1	1
Blade_UHF	315.0840	500	0.0	1	1
GPS_L1_Receiver	1575.4200	500	0.0	4	2

Selecting the GPS receiver in the window, we can then see the interference analysis (below) for that antenna. Selecting the type of interference we want to examine, we see the analysis and margin for that type of interference.

GPS_L1_Receiver (1575.4200 MHz)
- Co/Adjacent Channel Interference (2)
- Harmonic Interference (2)

Transmitter	f [MHz]	B [kHz]	EIRP [dBW]	Margin [dB]
Blade_VHF	131.2850	250	15.0	-18.4
Blade_UHF	315.0840	500	15.0	-2.4

GPS_L1_Receiver (1575.4200 MHz)
- Co/Adjacent Channel Interference (2)
- Harmonic Interference (2)

Transmitter	f [MHz]	B [kHz]	EIRP [dBW]	Margin [dB]
Blade_UHF	315.0840	500	15.0	-19.9
Blade_VHF	131.2850	250	15.0	-4.2

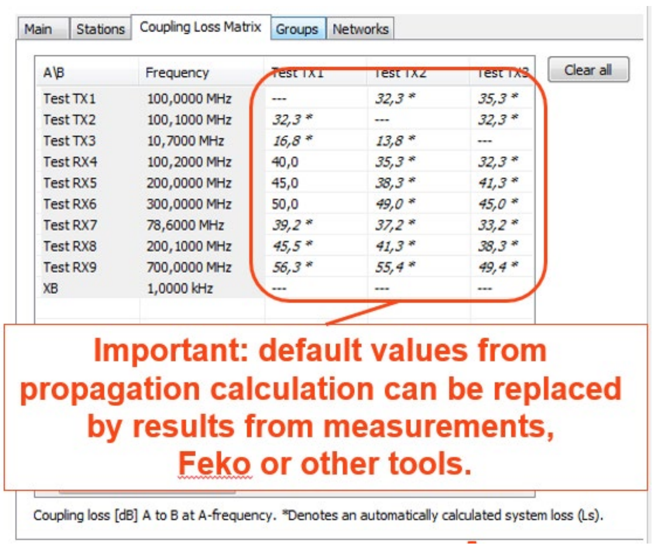
Antennas, of course, are never perfect. The electromagnetic energy transmitted by the UHF and VHF blade antennas outside of their transmission bands is never zero. Also, the GPS receiver's selectivity—its rejection of out-of-band signals—isn't perfect either. So, some of that power from the UHF and VHF antennas will affect the GPS receiver.

The WRAP toolset within Feko (hereafter also referred to as WRAP) quantifies that interference and the results are shown in the dialogue box. Both co/adjacent channel interference and interference from the harmonics of the UHF/VHF antennas can get into the GPS antenna, as shown by the negative margin readings within the dialogue box.

A negative margin indicates the number of decibels by which the noise floor is increased. In contrast, if you have a positive margin, that means that you have some elbow room: your transmitters could transmit additional power without affecting the GPS receiver. A negative margin indicates GPS reception is being degraded; in that case, users must make a judgement call on whether the amount of interference is acceptable or whether something must be done about it.

Isolation Between Stations

During the analysis setup, WRAP will request a coupling loss matrix. The coupling loss matrix is directly related to the antennas' S-parameter matrix. It's made up of the off-diagonal elements of the S-parameter matrix, but without the minus signs.


A\B	Frequency	Test TX1	Test TX2	Test TX3
Test TX1	100,0000 MHz	---	32,3 *	35,3 *
Test TX2	100,1000 MHz	32,3 *	---	32,3 *
Test TX3	10,7000 MHz	16,8 *	13,8 *	---
Test RX4	100,2000 MHz	40,0	35,3 *	32,3 *
Test RX5	200,0000 MHz	45,0	38,3 *	41,3 *
Test RX6	300,0000 MHz	50,0	49,0 *	45,0 *
Test RX7	78,6000 MHz	39,2 *	37,2 *	33,2 *
Test RX8	200,1000 MHz	45,5 *	41,3 *	38,3 *
Test RX9	700,0000 MHz	56,3 *	55,4 *	49,4 *
XB	1,0000 kHz	---	---	---

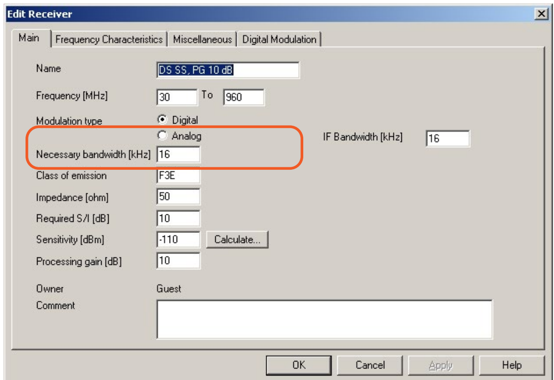
Values with asterisks indicate starting values proposed by WRAP. In the case of antennas mounted on aircraft, ships, and similar platforms, those proposed values may be too simplistic. Therefore, you'll likely want to turn to another tool—a general-purpose, full-wave 3D simulator like Feko, for example— to get your off-diagonal S-parameter measurements. You can then enter those parameters in WRAP via the dialogue box shown—along with various other properties of the electronics in the other dialogue windows—to get a far more accurate analysis.

Phenomena, Parameters, and Settings

Feko's WRAP technology includes facilities for entering parameters and settings to account for the full range of electromagnetic phenomena that can influence co-site interference.

Receivers

Receivers are sensitive and may suffer from interference by unwanted signals from transmitter antennas mounted on the platform. The Edit Receiver dialogue box allows Feko users to set and modify a variety of receiver parameters.

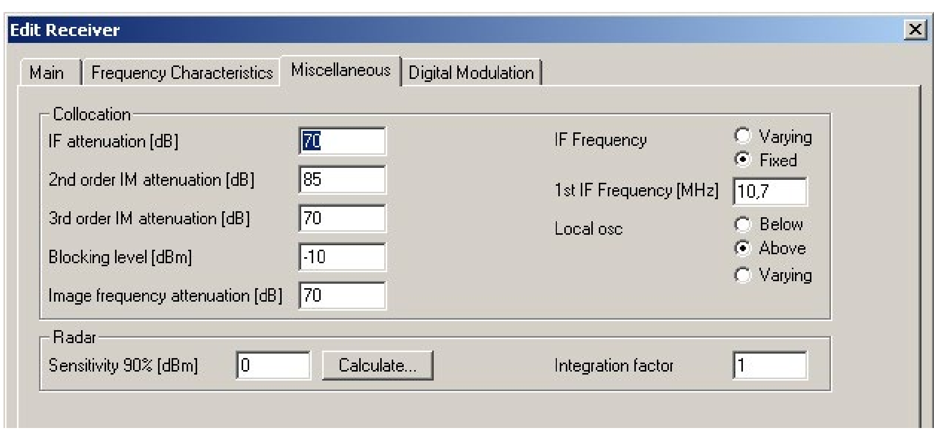


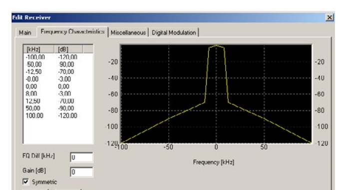
One important parameter is the receiver sensitivity in dBm, which is essentially the noise floor. Another is the required signal to interference ratio in dB, directly above the sensitivity setting. Next, there's the filter characteristic, which indicates how well the receiver rejects out-of-band signals from nearby transmitters.

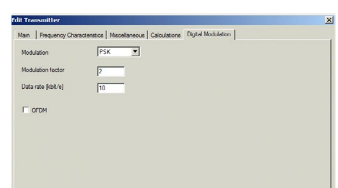
Obviously, receiver out-of-band rejection won't be perfect, so the filter characteristic curve can be included and modified to sharpen the analysis.

WRAP comes with a large, pre-installed database of electronics equipment characteristics and a number of templates you can use to emulate your own equipment. This library makes it easy to get started with the tool.

Finally, for digital receivers, digital modulation properties are included as well (below, right).



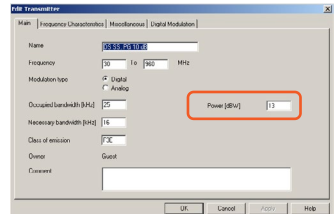


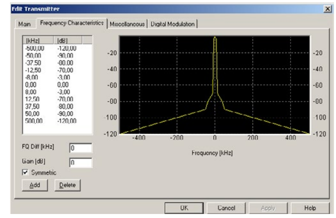


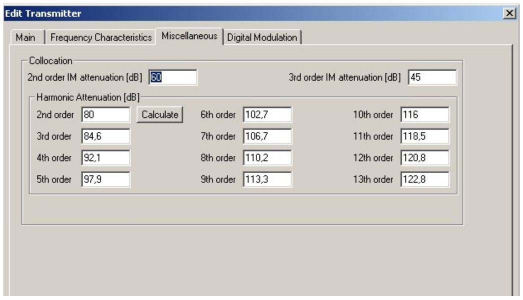
Transmitters

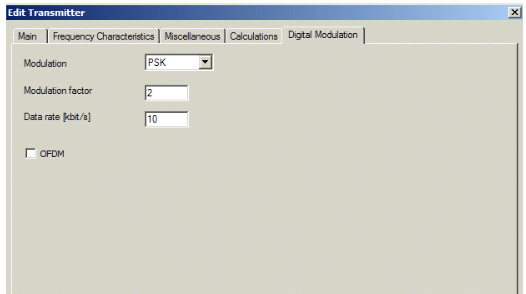
Feko's WRAP database also contains many transmitter systems and templates, the parameters of which can be modified via the Edit Transmitter dialogue box.

An important parameter on the main window is the transmitted power in dBW. Once again, as with receivers, transmitters aren't perfect. Some of their power is transmitted outside the intended frequency. WRAP allows you to account for this through the frequency characteristics window. Intermodulation (IM) and harmonic attenuation can be accounted for. And as for the receiver, the digital modulation properties for a digital transmitter can also be adjusted.



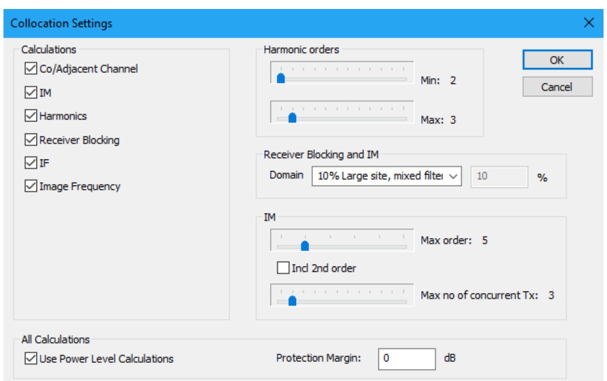






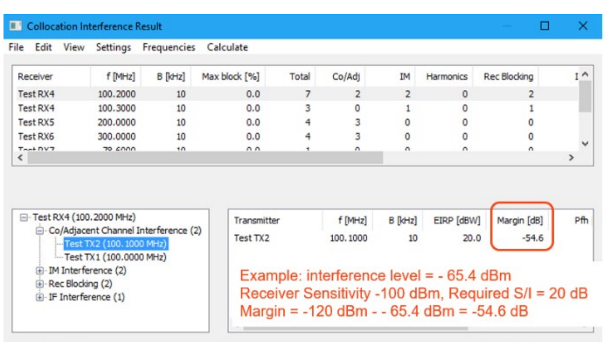
Calculation Settings

Before launching a simulation, users can specify which phenomena and how many harmonics to include. The tool performs these calculations quickly so users can ask for as much as they like without causing themselves undue delay.



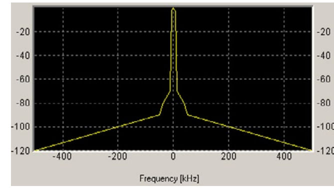
Key Result: Interference Margin

As mentioned earlier, the interference margin is a key result of the calculation. A noise floor of -54.6 dBm, as shown here, would in most cases be unacceptable, so users would know they must make some modifications (modify filters, place the antennas farther apart, etc.).



Co/Adjacent Channel Interference

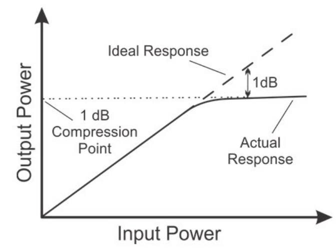
WRAP always calculates co-channel and adjacent channel interference, as equipment on different frequencies may interfere because parts of their spectra overlap. This can occur even as low as -120dB, because rejection of frequencies outside the band isn't perfect.



Accurate transmitter and receiver frequency characteristics for an enormous variety of equipment are included in the Feko database.

Receiver Blocking

Receivers are built to detect very small signals. So, when a strong transmitter is nearby, the receiver may become saturated. Receiver blocking is another phenomenon that WRAP quantifies.



Harmonics

As mentioned earlier, users can specify harmonic attenuation in the transmitter dialogue box. Harmonic interference of order n is present if:

In WRAP, the transmitter harmonic attenuation is included in the interference calculation. The basic transmission loss is calculated for each harmonic.

$$\left| n \times f_{Tx} - f_{Rx} \right| < \frac{B_{IF}}{2} + n \times \frac{B_{Tx}}{2}$$

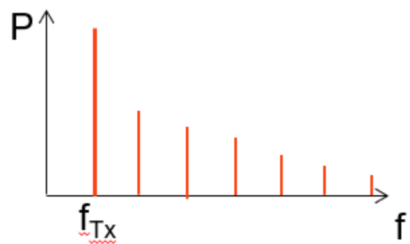
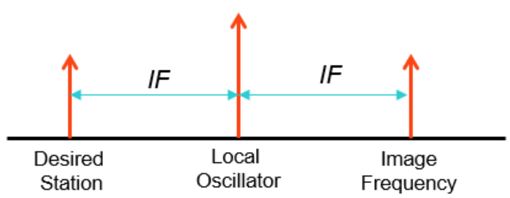


Image Frequency

Image frequency coincidence is present if:

$$\left| f_{image} - f_{Tx} \right| \leq \frac{B_{IF}}{2} + \frac{B_{Tx}}{2}$$



In superheterodyne receivers, frequencies on both sides of LO are converted down to intermediate frequency (IF). So, a station that's one IF away from the oscillator on the opposite side of the local oscillator (the image frequency) will enter the receiver just as easily as the desired station.
If the LO oscillator can be both above and below the tuned frequency of the receiver, WRAP evaluates both cases. For receivers with varying IF frequency, WRAP doesn't perform the image frequency interference test.

Intermediate Frequency Breakthrough

IF breakthrough is present if:

$$\left| IF - f_{Tx} \right| \le \frac{B_{IF}}{2} + \frac{B_{Tx}}{2}$$

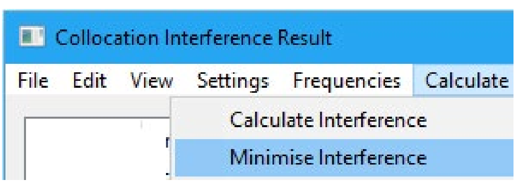
In other words, if an interfering transmitter is transmitting at the image frequency, it can break through.

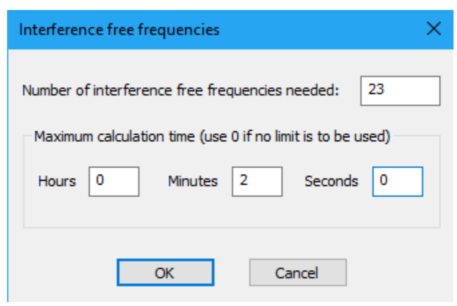
In WRAP, the receiver IF frequency attenuation is included in the interference calculation. If the local oscillator is above the tuned frequency, the selectivity curve is reversed. WRAP doesn't test for intermediate frequency breakthrough if the IF frequency of the receiver is varying.

Interference-Free Frequencies

In cases of communication networks with many transmitters and receivers, computing margins for each transmitter and receiver and then resolving all conflicts individually can be cumbersome and time-consuming. For these cases, WRAP provides a "Minimize Interference" option which automatically generates a user-specified number of interference-free frequencies.

WRAP considers IM, harmonics, and bandwidth for provided allotments of available frequencies. Numerous input parameters allow users to bound and refine their search, including maximum calculation time. The results can be saved as a new allotment or exported to a frequency list.





Spread Spectrum Interference in WRAP

Also included in WRAP are spread spectrum techniques. Transmitters and receivers don't all have to be fixed-frequency. Very often – especially in military applications – spread spectrum techniques are used. There are two of these: direct sequence and frequency hopping.

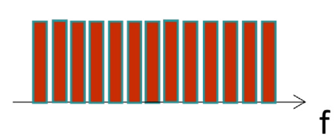
Direct-Sequence Spread Spectrum

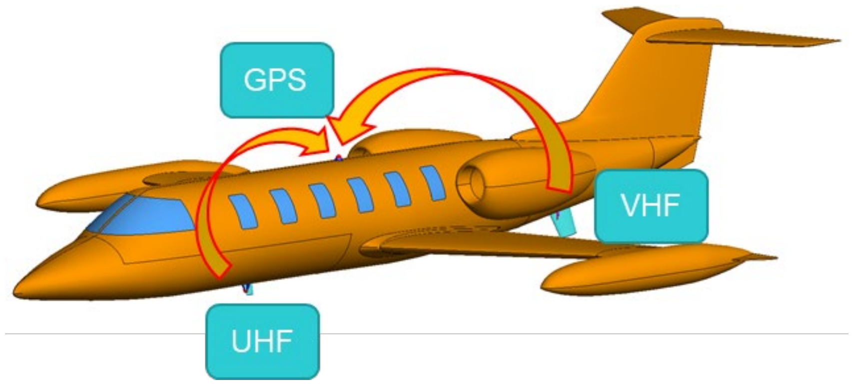
In direct-sequence spread spectrum (DSSS), the signal is spread out over a wide band in transmission. Then, after reception, de-spreading techniques are applied to improve the signal to noise ratio.

Frequency Hopping Spread Spectrum

In frequency hopping spread spectrum (FHSS), the system hops between frequencies to minimize the possibility of jamming. WRAP calculates and reports the percentage of hops that will encounter interference.

For hybrid DS/FH systems, WRAP reports interference as in the FHSS case (percentage of hops with interference) while also accounting for the DS processing gain.



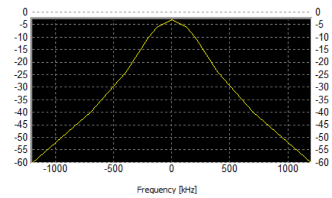


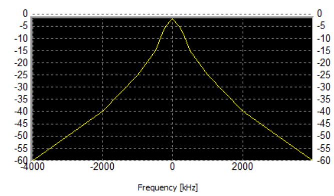
Solution to the Example Problem

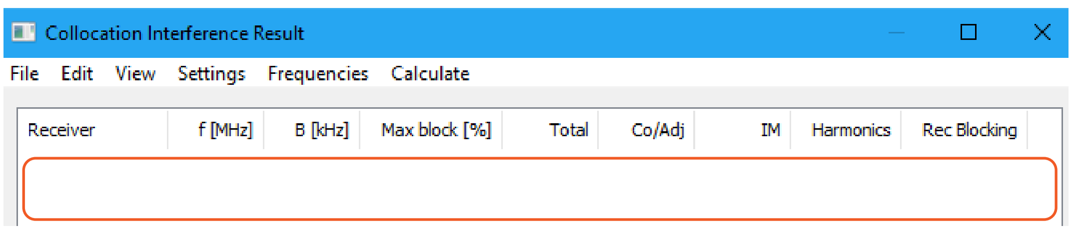
Now, let's return to the example problem we examined earlier—that of an aircraft's UHF and VHF antennas interfering with its GPS receiver—to see what we can do about it.

As previously mentioned, some of the higher order harmonics of the VHF and UHF receivers will enter the GPS receiver. Plus, the out-of-band rejection characteristic of the GPS receiver isn't perfect, allowing other frequencies from the two transmitters to enter as well.

WRAP's Collocation Interference Report indicated which interference problems are present. The next step is to find a solution. One solution could be to put a filter on the GPS receiver to improve the out-of-band rejection. Another solution is to put filters on the transmitters to improve suppression to out-of-band transmissions.







Each of these solutions can be accomplished easily using WRAP. Once the solution has been applied, the user can then re-run the collocation interference analysis again to ensure interference no longer occurs.

WRAP Technology Capabilities Within Altair Feko

Feko's WRAP solution offers a complete database of detailed propagation, transmitter, receiver, and filter models—with non-linear effects included—for analyzing electromagnetic interference. Fixed frequency, frequency hopping, and direct sequence spreading models are included. When antennas are close together, antenna coupling information can be imported into WRAP from Feko.

The software performs level calculations with spectrum and filtering by integration. It presents results at the RF signal level in detailed reports that spell out where problems are encountered. WRAP can also be used to predict interference-free frequencies for extensive communication networks.

WRAP makes it easy for users to analyze co-site interference on large multi-antenna platforms, make modifications to proposed configurations, and eliminate co-site interference problems.

For a detailed demonstration of Feko's WRAP capabilities and its ease of use, be sure to view Altair's webinar on this topic, which can be found here. Altair's full system solution for analysis of co-site interference is presented in this webinar, along with a practical example where an interference problem is identified and eliminated.