GSM and UMTS Intermodulation

Measurement standards and equipment for passive component intermodulation

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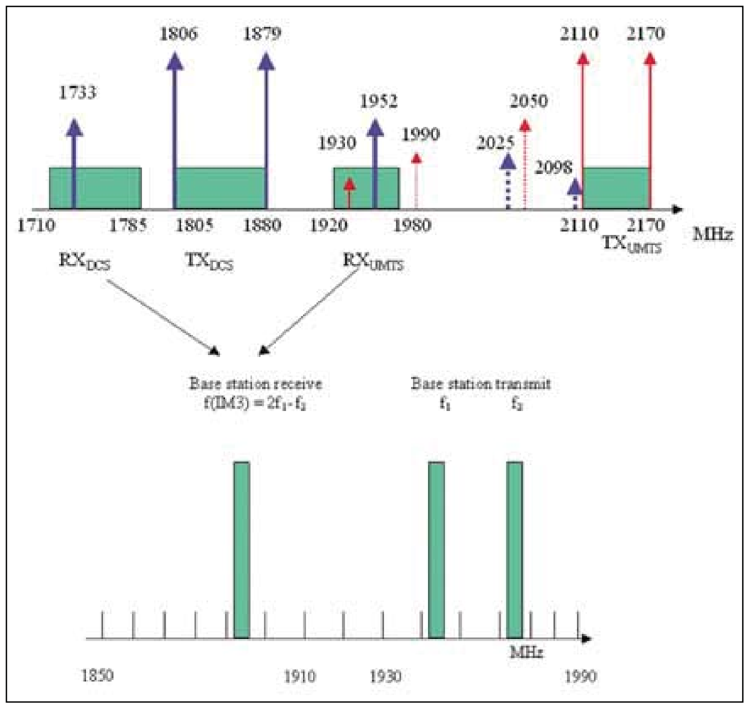
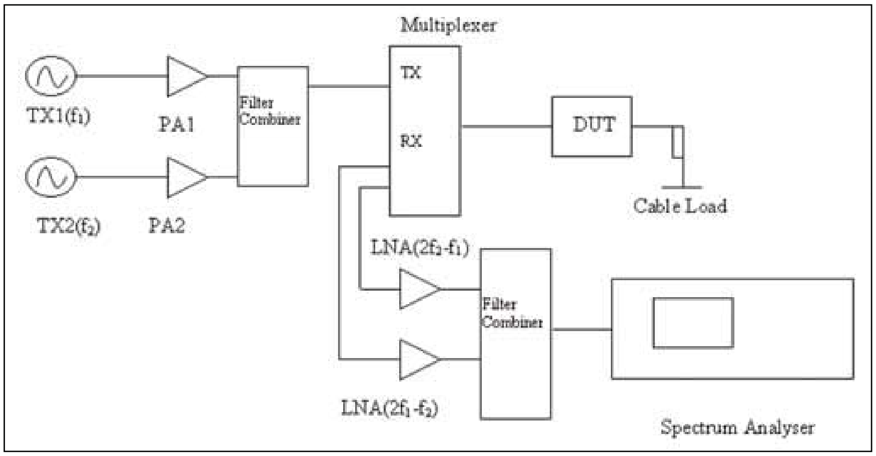
This article describes test procedures for wireless communication systems passive intermodulation (PIM). Specific examples are given for global system for mobile communications (GSM) and universal mobile telecommunications service (UMTS). PIM occurs whenever multiple signals at two or more frequencies interact in passive devices. The precise cause of PIM is difficult to determine but contact materials, oxide layers and dirt are involved. Poor mechanical contact, ferrous content of conductors in the radio frequency (RF) path and contamination of the RF conducting surfaces contribute to PIM.



▲ **Figure 1. Potential third-order modulation in GSM1800 and broadband UMTS [1] resulting from the co-location of multiple transceivers at a single site. UMTS Terrestrial Radio Access UTRA/FDD operates in either of the following paired frequency bands: 1920 to 1980 MHz uplink (mobile transmit) and 2110 to 2170 MHz downlink (base transmit) or 1850 to 1920 MHz uplink and 1930 to 1990 MHz downlink.**

PIM distortion is a significant factor limiting system capacity. As in active devices, PIM occurs when signals at multiple frequencies mix at nonlinearities to produce additional spurious signals. Spurious intermodulation (IM) signals may fall within a base station receive (uplink) band, as shown in Figure 1 for UMTS and GSM1800 [1], causing receiver desensitization. This degrades system carrier-to-interference (C/I) ratio, thereby reducing the capacity of the communications system.

PIM in passive devices is almost impossible to predict, hence measured data is used to characterize devices. The industry is using 100 percent production inspection of RF devices for base station applications to ensure that PIM levels are within specification because only minor changes in device construction can result in PIM levels out of the specification [2-7]. Base stations manufacturers for wireless communications systems, such as UMTS and GSM1800, use Deutsche Industrinorm (DIN) 7-16 and type-N coaxial connectors to handle the high transmit-power requirements. PIM in coaxial connectors



▲ **Figure 2. PIM measurement system architecture.**

are detectible at power levels greater than 1 watt [7]. This article discusses the difficulties in making PIM measurements, as well as potential solutions for UMTS and SGM1800 equipment manufacturers.

PIM measurements in GSM1800 and UMTS bands

A PIM measurement system architecture is shown in Figure 2. The two test carriers are amplified in PA1 and PA2 and then are summed in the filter combiner. The duplexer input is a bandpass filter tuned to the system transmit frequencies. This filtering reduces noise from the power amplifiers (typically –65 dBm) in the system receive band where the measurements are made. The test tones from the common port of the duplexer drive the device under test (DUT), which is terminated into a cable load. A 50 to 100 meter reel of low-level IM RG393 cable is terminated with a low-power termination. Most of the power is lost in the cable and most of the PIM generated by the termination is dissipated in the return path through the cable.

Cable is used as the primary termination to the DUT because terminations generate significant PIM. Reflected signals from the DUT return to the duplexer where a band-pass filter passes only the receive frequencies (i.e., the desired reflected PIM) and reduces the level of the two test carriers.

The carrier levels are still sufficient to cause IM in the low-noise amplifier (LNA) or spectrum analyzer front end, so an additional band pass filter is used between the duplexer and the LNAs. The LNAs have about 30 dB gain with a noise figure of 2 dB, thus effectively reducing the noise floor of the spectrum analyzer. This supports measurements to below –130 dBm. Since the contributors to PIM are generally unknown, it is important to test close to the point of manufacture. Maximum feedback is needed by those assembling the DUTs. The measurement system should be mobile within the manufacturing area. Software control ensures that the set up and measurement process is well controlled and it facilitates shop floor testing, which is essential for good production processes.

Statistical techniques are used to analyze processes and control software stores data to improve process reliability and efficiency. Tests use high power and are a potential hazard. Software control ensures that power is not applied out of sequence and provides adequate warning before power is applied. Timeouts also reduce the likelihood of equipment damage.

Testing requires a pair of cables between the DUT and the test set and they must be replaced regularly because they contribute to the measured PIM. Connectors must be aligned carefully and compressed air is used to clear foreign material prior to mating. The test fixture cables are clamped in fixed positions as far as possible and the DUTs are flexed to align with the test cables.

The technical specifications produced by the Third Generation Partnership Project (3GPP) [1] and the International Electrotechnical Commission [2] for third-order IM product measurement specify two continuous wave (CW) signal sources, each measuring +43 dBm (20 watts). Measurements are taken within the base station receive 1710 to 1785, 1850 to 1910 and 1920 to 1980 MHz bands when the two +43 dBm signals are tuned to fall within the corresponding base station transmit 1805 to 1880, 1930 to 1990 and 2110 to 2170 MHz bands. Twelve IM3 frequencies (1730, 1733, 1740, 1750, 1760, 1770, 1850, 1855, 1860, 1865, 1870 and 1952 MHz) are specified for measurements spanning the GSM and UMTS bands with maximum allowable power level –97 dBm. Two transmit carriers are applied: 1806 and 1879 MHz for GSM1800 and 2110 and 2170 MHz for UMTS. These carriers produce in-band IM at 1733 MHz and 1952 MHz, as shown in Figure 1.

Measurements at 1730, 1740, 1750, 1760 and 1770 MHz can be obtained in two ways: holding source one at 1805 MHz and sweeping source two downward from

IM3 MHz	PIM dBm	Result
1730	–131	Pass
1733	–129.7	Pass
1740	–129.5	Pass
1750	–129.1	Pass
1760	–128.9	Pass
1770	–128.3	Pass
1850	–127.5	Pass
1855	–127.1	Pass
1860	–126.7	Pass
1865	–125.9	Pass
1870	–125.5	Pass
1952	125.1	Pass

▲ **Table 1. Summary of the measured results.**

1880 to 1840 MHz in steps of 10 MHz; or holding source two at 1880 MHz and sweeping source one upward from 1805 to 1825 in steps of 5 MHz. Likewise, measurements at 1850, 1855, 1860, 1865, and 1870 MHz can be obtained in two ways: holding source one at 1930 MHz and sweeping source tow downward from 1990 to 1970 MHz in steps of 5 MHz or holding source two at 1990 MHz and sweeping source one upward from 1920 to 1930 in steps of 2.5 MHz.

Typical resulting PIM measured results for GSM and UMTS bands antenna cable are repeatable and well within specifications, as shown in Table 1.

Measurement uncertainty

The uncertainty in the PIM measurements system shown in Figure 2 is calculated by the following relation:

$$RSS = \sqrt{\begin{matrix}(\delta A)^2 + (\delta Pm)^2 + (\delta Pg)^2 \\ +(\delta D)^2 + (\delta \,\mathrm{Pr})^2\end{matrix}}$$

where δA, δPm, δPg, δD and δPr are the uncertainties introduced by the attenuation, power meter, generator, distance of self-intermodulation of the test bench and intermodulation of the DUT and, finally, the receiver, respectively. Mismatch uncertainties are not included.

Filters, cables and connectors create residual IM interference, which reduces the measurement system performances. Hence, after any calibration, the residual IM level is measured using a low-IM 50-ohm termination. The measurement reference is located at the antenna port of the duplexer and, therefore, the attenuation of the RX path must be measured and used as an offset for the spectrum analyzer. This attenuation occurs in the measurement cable, the duplexer and all cables. Finally, the gain of the LNA is added.

PIM is normally measured using two test carriers with 43 dBm at the DUT port, although another power level could be used. The calibration of each carrier level is done using a calibrated power meter in place of the DUT. The signal amplitude of the generators is adjusted for the desired output at the measurement port.

Conclusion

When transmitted signals are passed through antenna cables, IM can be caused, especially at connections. This IM looks just like the receive signal to the base station. The result is poor reception at the base station and poor call quality with the reduced capacity of the communications systems.

This work not only revealed the difficulties that industry is experiencing in making PIM measurements, but also provided UMTS and GSM1800 equipment manufacture companies with a tool to improve their measurement capabilities as they deal with PIM-related barriers. Today, manufacturers are producing components for the third generation of mobile communications, and PIM is a major criterion for original equipment manufacturers (OEMs). ■

Acknowledgement

The authors wish to acknowledge the assistance and support from the UK Department of Trade & Industry.

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