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Contents

Foreword

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1 Scope

The present document is the technical report for the study item on Passive InterModulation (PIM) handling for Base Stations, which was approved at TSG RAN#55. The objective of the WI is to investigate the PIM issue from an overall perspective and to conclude on a way forward for the PIM problem and propose corresponding requirements for the BS specifications.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

[1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".

[2] Roy Naddaf, Rune Johansson, Bo Franzon, "Passive Intermodulation in Real Networks", MULCOPIM '08 conference 24-26 September 2008, Valencia, Spain.

[3] 3GPP TS 25.104: "Base Station (BS) radio transmission and reception (FDD)".

[4] 3GPP TS 36.104: "Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception".

[5] 3GPP TS 37.104: "E-UTRA, UTRA and GSM/EDGE; Multi-Standard Radio (MSR) Base Station (BS) radio transmission and reception".

[6] Kaelus, White Paper, "Passive Intermodulation (PIM) Testing Guidelines", http://www.kaelus.com/Kaelus/media/Site/QR Code Files/PIM-Testing-Guidelines_Brochure.pdf.

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the terms and definitions given in TR 21.905 [1] apply.

3.2 Abbreviations

For the purposes of the present document, the abbreviations given in TR 21.905 [1] and the following apply.
An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in TR 21.905 [1].

AAS Active Antenna System
ANP Antenna-Near Part
BW BandWidth
CA Carrier Aggregation

CS	Capability Set
CW	Continuous Wave (un-modulated signal)
IM	InterModulation
IMx	x^{th} order InterModulation
LNA	Low Noise Amplifier
MB-MSR	Multi-Band - Multi-Standard Radio
MSR BS	Multi-Standard Radio Base Station
MSR-NC	Multi-Standard Radio in Non-Contiguous spectrum
NC-CA	Non-Contiguous Carrier Aggregation
NC-HSDPA	HSDPA in Non-Contiguous spectrum
PA	Power Amplifier
PAR	Peak-to-Average Ratio
PIM	Passive InterModulation
PSD	Power Spectral Density
RAT	Radio Access Technology
RFBW	Radio Frequency BandWidth
TMA	Tower-Mounted Amplifier
WA	Wide Area

4 General

The impact of Passive InterModulation (PIM) on Base Station (BS) receiver performance has been extensively discussed in RAN4 in relation to the MSR-NC work. It has been shown that the degradation depends on several factors and can in some cases be quite severe (over 10 dB). It was also concluded that putting requirements only on the BS will not solve the issue, since PIM can be generated in the complete site infra-structure, including the antennas. For this reason, the PIM issue needs to be addressed from a broader BS site and infrastructure point view in a separate study item.

4.1 Work item objective

This study investigates the PIM issue from an overall perspective and concludes on a way forward for the PIM problem and proposes corresponding requirements for the BS specifications. Primary focus:

1. Understand the overall PIM mechanism, impact and level of degradation considering the PIM performance of the complete site infrastructure, including the BS.

2. Conclude on reasonable new PIM-related requirements for the BS, set in relation to the site infra-structure PIM performance. Existing BS RF requirements and tests remain unchanged. Investigate and define applicability conditions of new PIM-related requirements.

3. Consider and develop test methods so that the PIM performance can be captured and tested properly

The following specification-related work will be required:

1. In the present document, identify possible site deployment aspects, possible counter measures and way forward, which should serve as a deployment guideline.

2. Identify the corresponding requirements needed and their applicability for the BS core and test specifications, based upon the outcome of the present document.

5 Scenarios for PIM

5.1 Site scenarios

The possibility of interference from PIM in wireless communication system is a well-known phenomenon. The detailed mechanism behind PIM generation is described in clause 6. If the interference fall into the receiver band may cause degradation of receiver sensitivity.

Figure 5.1-1 shows a typical interference scenarios for a BS, where PIM generated within the site creates potential interference to the BS own receiver. This is a major interference scenario in broad bandwidth and/or non-contiguous spectrum operation. It includes two categories: single band transmission and multi-band transmission sharing the antenna system. The duplexer, jumper cable, feeder cables, antenna, and the connectors between them are major potential sources of PIM. Scenarios where interference is created outside the site or when the interference victim is another BS are not covered by the present document.

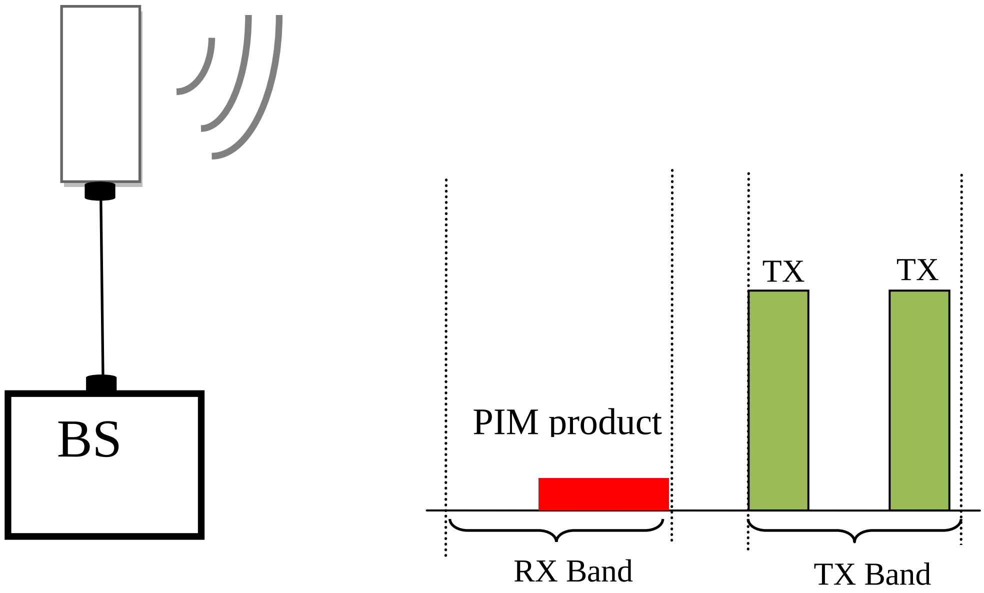

Figure 5.1-1: PIM interference to the receiver of own BS

PIM can also be generated within site equipment that is shared between operators. The transmitter source causing the PIM can then potentially be another operator's BS sharing the site in the same band or an adjacent band.

5.2 Single-band scenarios

Operation of MSR BS in Non-Contiguous spectrum (MSR-NC) enables transmission on carriers with a large frequency separation within a band, potentially giving very high RF bandwidths. Considering the frequency domain relations for the generation of passive InterModulation (IM) products, the existing paired bands can be divided into two categories. For the first category, the relation between band size and duplex gap size implies that third order PIM products would never fall in the own receive band, irrespective of RF BW. For the second category of bands, due to the "small" duplex gap, the own receiver could potentially suffer sensitivity degradation from IM3 products, depending on the size of the RF BW. Table 5.2-1 summarizes the IM3 analysis for the paired bands, while Table 5.2-2 gives the maximum RF BW which would not cause IM3 in the own receiver for the concerned bands. Note that there are additional new bands under standardization such as band 26, 27 and 700 APAC, which also could suffer from passive IM3 into own Rx.

The maximum RF BW without IM3 in own receive band is equal to the UL-DL separation divided by 2, as given in Table 5.2-2. For higher order 5^{th,} 7th and 9th order PIM, the maximum RF BW without IM in own receive band is equal to the UL-DL separation divided by 3, 4 and 5 respectively. As is noted later in the present document, the higher order PIM processes also contribute to the IM products at the frequencies of lower order products.

One additional aspect for MSR-NC in multi-RAT operation is that for narrowband systems such as GSM, the IM products are also narrowband, while the IM products from wide band carriers or combination of wideband and narrowband carriers in multi-RAT operation will be broadband. Due to the broadband nature of PIM for multi-RAT transmissions and the fact that the PIM level possibly increases with the number of carriers, single-RAT features that rely on narrowband properties such as GSM frequency hopping will not be a solution to the PIM problem.

Thus, MSR-NC is clearly a relevant scenario for the PIM studies.

Table 5.2-1: IM3 analysis for paired bands in E-UTRA, UTRA and GSM/EDGE

MSR and E-UTRA Band number	UTRA Band number	GSM/EDGE Band designation	Uplink (UL) BS receive UE transmit	Downlink (DL) BS transmit UE receive	Duplex gap size in relation to Band size
1	I	-	1920 MHz – 1980 MHz	2110 MHz – 2170 MHz	Large
2	II	PCS 1900	1850 MHz – 1910 MHz	1930 MHz – 1990 MHz	Small
3	III	DCS 1800	1710 MHz – 1785 MHz	1805 MHz – 1880 MHz	Small
4	IV	-	1710 MHz – 1755 MHz	2110 MHz – 2155 MHz	Large
5	V	GSM 850	824 MHz – 849 MHz	869 MHz – 894MHz	Small
6	VI	-	830 MHz – 840 MHz	875 MHz – 885 MHz	Large
7	VII	-	2500 MHz – 2570 MHz	2620 MHz – 2690 MHz	Small
8	VIII	E-GSM	880 MHz – 915 MHz	925 MHz – 960 MHz	Small
9	IX	-	1749.9 MHz – 1784.9 MHz	1844.9 MHz – 1879.9 MHz	Large
10	X	-	1710 MHz – 1770 MHz	2110 MHz – 2170 MHz	Large
11	XI	-	1427.9 MHz – 1447.9 MHz	1475.9 MHz – 1495.9 MHz	Large
12	XII	-	699 MHz – 716 MHz	729 MHz – 746 MHz	Small
13	XIII	-	777 MHz – 787 MHz	746 MHz – 756 MHz	Large
14	XIV	-	788 MHz – 798 MHz	758 MHz – 768 MHz	Large
15	XV	-	Reserved	Reserved	
16	XVI	-	Reserved	Reserved	
17	-	-	704 MHz – 716 MHz	734 MHz – 746 MHz	Large
18	-	-	815 MHz – 830 MHz	860 MHz – 875 MHz	Large
19	XIX	-	830 MHz – 845 MHz	875 MHz – 890 MHz	Large
20	XX	-	832 MHz – 862 MHz	791 MHz – 821 MHz	Small
21	XXI	-	1447.9 MHz – 1462.9 MHz	1495.9 MHz – 1510.9 MHz	Large
22	XXII	-	3410 MHz – 3490 MHz	3510 MHz – 3590 MHz	Small
23	-	-	2000 MHz – 2020 MHz	2180 MHz – 2200 MHz	Large
24	-	-	1626.5 MHz – 1660.5 MHz	1525 MHz – 1559 MHz	Large
25	XXV	-	1850 MHz – 1915 MHz	1930 MHz – 1995 MHz	Small
26			814 MHz – 849 MHz	859 MHz – 894 MHz	Small
27			807 MHz – 824 MHz	852 MHz – 869 MHz	Large
28 (APAC700)			703 MHz – 748 MHz	758 MHz – 803 MHz	Small

Table 5.2-2: Maximum RF BW to avoid IM3 in own receiver for bands with "small" duplex gap.

MSR Band number	UTRA Band number	GSM/EDGE Band designation	Uplink (UL) BS receive UE transmit	Downlink (DL) BS transmit UE receive	Maximum RFBW without IM3 in own Rx
2	II	PCS 1900	1850 MHz – 1910 MHz	1930 MHz – 1990 MHz	40 MHz
3	III	DCS 1800	1710 MHz – 1785 MHz	1805 MHz – 1880 MHz	47.5 MHz
5	V	GSM 850	824 MHz – 849 MHz	869 MHz – 894MHz	22.5 MHz
7	VII	-	2500 MHz – 2570 MHz	2620 MHz – 2690 MHz	60 MHz
8	VIII	E-GSM	880 MHz – 915 MHz	925 MHz – 960 MHz	22.5 MHz
12	XII	-	699 MHz – 716 MHz	729 MHz – 746 MHz	15 MHz
20	XX	-	832 MHz – 862 MHz	791 MHz – 821 MHz	20,5 MHz
22	XXII	-	3410 MHz – 3490 MHz	3510 MHz – 3590 MHz	50 MHz
25	XXV	-	1850 MHz – 1915 MHz	1930 MHz – 1995 MHz	40 MHz
25	XXV	-	1850 MHz – 1915 MHz	1930 MHz – 1995 MHz	40 MHz
26			814 MHz – 849 MHz	859 MHz – 894 MHz	22.5 MHz
28 (APAC700)			703 MHz – 748 MHz	758 MHz – 803 MHz	27.5 MHz

Based on RAN4 decision, NC-HSDPA and NC-CA are developed for both MSR 3GPP TS 37.104 [5] and single RAT specifications (3GPP TS 25.104 [3] and 3GPP TS 36.104 [4]). This means that single RAT aspects of non-contiguous operation PIM should be considered and handled in the corresponding specification.

5.3 Multiband scenarios

5.3.1 Dual band HSDPA, LTE inter-band CA and MB-MSR

There are currently a large number of band combinations supporting dual band HSDPA and/or LTE CA which are either already defined or under standardization in 3GPP.

In previous RAN4 work, the potential for harmonics and intermodulation generation of a number of inter-band CA combinations were discussed. Thus dual band HSDPA and LTE inter-band CA are also relevant scenarios for PIM. The exact combinations to handle will require further investigation.

Similar with dual band HSDPA and LTE inter-band CA, MB-MSR are also relevant scenarios for PIM. As long as BS transmits through one common antenna connector for multiband scenarios, the PIM interference may cause receiver sensitivity degradation of another co-located BS or own BS.

For the case interference to another co-located BS, the existing emission requirements for co-location with other BSs, i.e. -96 dBm/100KHz still works well, but is not included in present study. For the case interference to the receiver of own BS, the requirement and test require further investigation.

While co-location is not part of the present study, there are scenarios where site equipment is shared between co-located operators. This is the case for indoor systems, especially in public places such as railway stations, where it is common that all operators share the same distributed antenna system over a multi-operator combiner. Within a band or for bands that are close to each other, shared infrastructure can generate PIM into the receiver, where the transmitter source causing the PIM can then potentially be another operator's BS sharing the site in the same band or an adjacent band.

5.4 Other scenarios

All other scenarios where PIM generation occur due to circumstances external to the site infra-structure are beyond RAN4 study areas and are not included in the study item.

Active Antenna Systems (AAS) are not within the scope of the present study.

6 PIM generation from site infra-structure

6.1 Mechanism for PIM generation

With introduction of MSR in non-contiguous spectrum, there are new implications for the RF characteristics. These are related to the extension of the RF bandwidth to cover non-contiguous spectrum scenarios, plus the combination of carriers with narrowband/high Power Spectral Density (PSD) and broadband /low PSD carriers for the different RATs. One of the most challenging implications is the possible generation of Passive InterModulation (PIM) products into the own receive band, which could degrade the receiver sensitivity due to the resulting noise increase.

There are additional scenarios relevant to BS PIM, considering recent features added to 3GPP specifications. For dual band HSDPA and inter-band CA for E-UTRA, there are band combinations that would potentially cause PIM into own receive band. In addition, the new work item for multi-band MSR BS with potentially very wide band transmitters and receivers would lead to new PIM scenarios.

Passive InterModulation (PIM) occurs due to the non-linear nature of passive components and has traditionally been a major concern when deploying cellular networks. Nonlinearities will always be present in components and interfaces due to material imperfections, and highlights the needs for high-quality materials and finishes. For GSM networks, PIM was handled initially through non-duplexed equipment, which gives at least 30 dB isolation between RX and TX. For duplexed equipment, it is handled through frequency planning and frequency hopping. For broadband systems such as UTRA, that have limited RF BW, the lower order IM products do not hit the own receive band and carriers have low PSD. For these reasons, the passive IM does not contribute to any degradation of the receiver. The situation becomes different for wider RF BW in combination with high PSD carriers.

PIM products can be generated from the antenna port of the duplexer in the BS, through connectors, jumper cable, feeder cables, site equipment and antennas, all the way up to and including the antennas, as shown in figure 6.1-1. Some of the mechanisms behind passive IM generation are as follows:

- Corrosion, Oxides (due to aging, i.e., can vary over time)
- Dissimilar metals in contact to each other
- Magnetic or paramagnetic materials in the signal path
- Sharp edges in connectors, causing corona generation
- Defects in workmanship
- Low contact pressure and small contact area
- Debris, pollution and dust at the contact areas
- Vibration
- Temperature variation

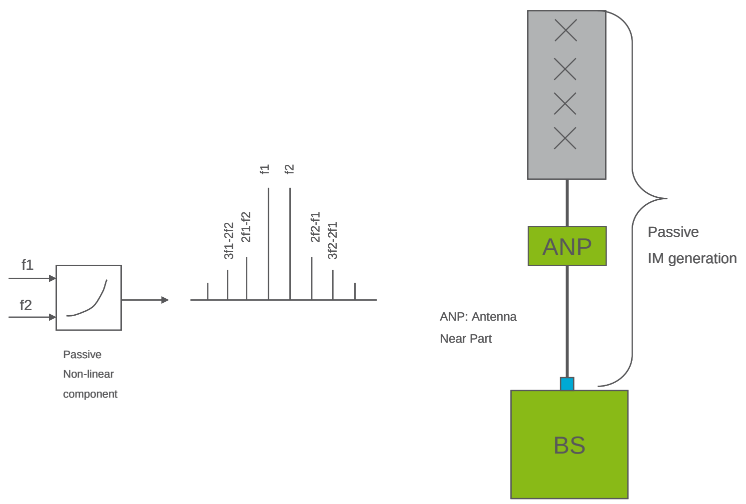

Figure 6.1-1: PIM and PIM generation path

InterModulation (IM) products occur at frequencies $\left| \pm mf_1 \pm nf_2 \right|$ where the order of IM products is $(m+n)$.

The third order IM products have the highest level, while the level gradually decreases for higher order products.

Considering the frequency domain relations for the generation of IM products, the existing paired bands can be divided into two categories. For the first category, the relation between band size and duplex gap size implies that IM3 products would never fall in the own receive band, irrespective of RF BW. For the second category of bands, due to the "small" duplex gap, the own receiver could potentially suffer sensitivity degradation from IM3 products, depending on the size of the RF BW. Note that there are additional new bands under standardization such as band 26, 27 and 700 APAC, which also could suffer from passive IM3 into own Rx. Higher-order PIM may have to be considered for cases where 3rd order PIM is not a problem, see clause 5.2.

The IM products are thus dependent on several parameters such as:

- Number of transmitted carriers
- Type of carrier (modulation, amplitude components of the carrier (peak to average), bandwidth, output power per carrier type)
- Frequency relation between carriers.
- Total RF Bandwidth of the transmitted multicarrier signal

The impact of PIM can depend on frequency and can be higher at lower frequencies. One reason for this is that the PIM source is often not located close to the point of the input signal and will experiences frequency dependent losses, for example in the antenna feeder. At the PIM source, e.g. antenna, the signal level will be lower at higher frequencies and therefore there will be less impact compared to lower frequencies.

In praxis PIM does normally not increase with third order as predicted by theory. Usually PIM increases with less than 3 dB for every 1 dB change in input signal level. This is as PIM sources are often not localised at one point and the overall PIM effect can be rather complex.

A theoretical background for PIM is given in sub-clause 6.1.1:

6.1.1 Theoretical background for 3rd order Passive InterModulation (PIM)

When non-linear relationship exists between current and voltage (or, conversely, between the electric and magnetic components of a propagating wave), harmonic frequencies and linear integral combinations of them will be generated. As an illustration, consider a component with a voltage-current relationship given by

$$V = a_0 + a_1 I + a_2 I^2 + a_3 I^3 + \ldots \qquad \textbf{(1)}$$

and let the current be of the form

$$I(t) = I_1 \cos\omega_1 t + I_2 \cos\omega_2 t \qquad \textbf{(2)}$$

where $w_i = 2\pi f_i$ and f_i represents the frequency in Hertz. An interpretation of (1) is that V is the result when a signal I is applied to a network characterized by the a_i terms. The a_i terms thus represent both the physical properties of the non-linearity and the circuit impedances in which the non-linearity is embedded. Concentrating on the third-order term we find:

$$V(t) = \ldots + a_3 \begin{bmatrix} \frac{3I_1}{2}(\frac{I_1^2}{2} + I_2^2)\cos\omega_1 t + \frac{3I_2}{2}(I_1^2 + \frac{I_2^2}{2})\cos\omega_2 t + \frac{I_1^3}{4}\cos 3\omega_1 t + \frac{I_2^3}{4}\cos 3\omega_2 t \\ + \frac{3I_1^2 I_2}{4}\cos(2\omega_1 - \omega_2)t + \frac{3I_1^2 I_2}{4}\cos(2\omega_1 + \omega_2)t \\ + \frac{3I_1 I_2^2}{4}\cos(2\omega_2 - \omega_1)t + \frac{3I_1 I_2^2}{4}\cos(2\omega_2 + \omega_1)t \end{bmatrix} + \ldots \qquad \textbf{(3)}$$

In this expression we notice the presence of the harmonics $3\omega_1$ and $3\omega_2$ as well as the sums and differences $(2\omega_1 \pm \omega_2)$ and $(2\omega_2 \pm \omega_1)$. These sums and differences are commonly referred to as third order intermodulation products.
If the Taylor series is limited to 3rd order non-linearities (a_1, $a_3 \neq 0$), it predicts only IM3 products with a ''1 dB - 3 dB' power relation. This means a 1 dB increase of carrier power results in a 3 dB increase of IM3 power.

However, the fifth, seventh, ninth and higher order terms also produce these same "third order" intermodulation frequencies. This can be proven mathematically by writing the higher order term as the product of two lower order terms. The expansion for the fifth order term is shown below:

$$
\begin{aligned}
&a_5 \cdot \left(I_1 \cos(\omega_1 t) + I_2 \cos(\omega_2 t)\right)^5 = \\
&a_5 \cdot \left(I_1 \cos(\omega_1 t) + I_2 \cos(\omega_2 t)\right)^2 \cdot \left(I_1 \cos(\omega_1 t) + I_2 \cos(\omega_2 t)\right)^3 = \\
&a_5 \cdot \left[\frac{I_1^{\,2}}{2} + \frac{I_2^{\,2}}{2} + \frac{I_1^{\,2}}{2} \cdot \cos(2\omega_1 t) + \frac{I_2^{\,2}}{2} \cdot \cos(2\omega_2 t) + I_1 \cdot I_2 \cdot \left(\cos(\omega_1 - \omega_2)t + \cos(\omega_1 + \omega_2)t\right)\right] \cdot \\
&\cdot \left[\begin{aligned}&\frac{3I_1}{2}\left(\frac{I_1^2}{2} + I_2^2\right) \cdot \cos\omega_1 t + \frac{3I_2}{2}\left(I_1^2 + \frac{I_2^2}{2}\right) \cdot \cos\omega_2 t + \frac{I_1^3}{4} \cdot \cos 3\omega_1 t + \frac{I_2^3}{4} \cdot \cos 3\omega_2 t \\
&+ \frac{3I_1^2 I_2}{4} \cdot \left(\cos(2\omega_1 - \omega_2)t + \cos(2\omega_1 + \omega_2)t\right) + \frac{3I_2^2 I_1}{4} \cdot \left(\cos(2\omega_2 - \omega_1)t + \cos(2\omega_2 + \omega_1)t\right)\end{aligned}\right]
\end{aligned}
\qquad \textbf{(4)}
$$

Making use of the trigonometric identity,

$$
\cos(x) \cdot \cos(y) = \frac{1}{2}\left(\cos(x+y) + \cos(x-y)\right), \qquad \textbf{(5)}
$$

it is readily apparent which products in equation (4) produce distortion at a given frequency. For instance, for a non-linearity with a third and a fifth order term, the component at frequency ($2\omega_1$- ω_2) is given by

$$
\left\{\begin{aligned}&a_3 \cdot \frac{3I_1^2 I_2}{4} \\
&+ a_5 \cdot \left[\left(\frac{I_1^{\,2}}{2} + \frac{I_2^{\,2}}{2}\right) \cdot \frac{3I_1^2 I_2}{4} + \frac{I_1^{\,2}}{4} \cdot \frac{3I_2^2 I_1}{4} + \frac{I_2^{\,2}}{4} \cdot \frac{3I_1^2 I_2}{4} + I_1 \cdot I_2 \cdot \frac{3I_1}{4}\left(\frac{I_1^2}{2} + I_2^2 + \frac{I_1^{\,3}}{4}\right)\right]\end{aligned}\right\} \cdot \cos(2\omega_1 - \omega_2)t \qquad \textbf{(6)}
$$

At small signal levels it is common practice to ignore the higher order coefficients. By simplifying the formula, i.e., by assuming that only a_3 is non-zero, it is evident from equation (6) that the intermodulation power at frequency ($2\omega_1$- ω_2) increases by 2 dB per dB with signal amplitude I_1 and by 1 dB per dB with signal amplitude I_2. However, at the high signal levels where passive intermodulation is problematic, this simplification is no longer valid. It is evident from equation (6) that when a_5 and higher order coefficients are non-zero, the relation between signal and intermodulation power is quite complex and depends on all coefficients in the power series. This explains why the slope of the measured PIM power versus signal power curve deviates from the "theoretical" value and is different for each passive non-linearity. Papers have suggested use of hyperbolic tangent or arc-tangent functions with adapted coefficients to describe these effects, but have not provided additional insight.

Equation (6) also illustrates the problem of computing the relationship between PIM power for modulated signals versus Continuous Wave (CW) signals. With modulated signals, the envelopes I_1 and I_2 are time-varying, statistical variables. With only a_3 non-zero, the average power (amplitude-squared) of the intermodulation product at frequency ($2\omega_1$- ω_2) is proportional to the fourth moment of I_1 and the second moment of I_2, where the n-th moment of I is defined as the average of I^n. Note that the second moment of the envelope equals the signal power. Thus, with only a_3 non-zero, the power of the intermodulation product at frequency ($2\omega_1$- ω_2) does not depend on the modulation of the signal at frequency ω_2. However, when a_5 and higher order coefficients are non-zero, higher order moments become relevant in the relation between modulation type and intermodulation power. For instance, for a non-linearity with up to fifth order terms, up to the eighth order moment of I_1 and the sixth order moment of I_2 are relevant at the given intermodulation frequency.

Although the frequency term cos($2\omega_1$- ω_2) in equation (6) does not depend on the order of the non-linearity, it should be noted that the envelopes I_1 and I_2 contribute their own modulation spectrum to the intermodulation product. Thus even the shape of the intermodulation product at a "third order" intermodulation frequency depends on the higher order non-linear coefficients.

The above analysis demonstrates that simulations of PIM power are of questionable value without accurate determination of the higher order coefficients of the non-linearity. An abstract intermodulation model could be substituted for the physical model suggested by (1), but the above analysis demonstrates that the generality of the model cannot be guaranteed. The analysis also demonstrates that there is no universally valid relationship between signal powers, signal modulations and PIM power.

Two possible approaches are recommended for any further empirical investigation:

1. Characterize several types of passive non-linearities over a wide range of CW powers and fit the non-linear coefficients in a simulation model to the measurements. Next, use these fitted coefficients in a simulation model with modulated signals.

2. Characterize several types of passive non-linearities with CW signals as well as with modulated signals.

The advantages of the first approach are that relatively accurate measurements can be performed with standardized measurement equipment and that the effect of modulation can be studied by simulation. The disadvantage is that it is difficult to judge the effect of estimation errors in the non-linear coefficients and of truncating the non-linearity power series. The advantage of the second approach is that it measures the conversion factor between modulated and CW signals directly.

However for practical approach it is helpful to start with a formula for the upper bound.

In general, for the complete series expansion, all higher harmonics as well as their sums and differences, i.e. frequencies of the form

$$\left| \pm m f_1 \pm n f_2 \right| \qquad \textbf{(7)}$$

would appear, where m and n are positive integers. These frequencies are referred to as intermodulation products of order (|m|+|n|). Thus, the spurious signals due to the third-order term are intermodulation products of order three. Equation (3) also demonstrates that, for equal amplitudes I_1 and I_2, the power of the third-order intermodulation signal will increase, at least theoretically, with the third power of the transmitted signal strength. Intermodulation products where |m-n|=1 have the potential to be particularly troublesome.

Third order intermodulation products are formed from the sum and difference frequencies. In this expression, we notice four intermodulation products with order three:

$$\begin{aligned} w_a &= 2w_1 - w_2 \\ w_b &= 2w_1 + w_2 \\ w_c &= 2w_2 - w_1 \\ w_d &= 2w_2 + w_1 \end{aligned}$$

For the difference frequencies we have:

Amplitude of $w_a = \log(3a_3 I_1^2 I_2 / 4) = \log(3a_3/4) + 2\log I_1 + \log I_2$

Amplitude of $w_c = \log(3a_3 I_1 I_2^2 / 4) = \log(3a_3/4) + \log I_1 + 2\log I_2$

For the sum frequencies we have:

Amplitude of $w_b = \log(3a_3 I_1^2 I_2 / 4) = \log(3a_3/4) + 2\log I_1 + \log I_2$

Amplitude of $w_d = \log(3a_3 I_1 I_2^2 / 4) = \log(3a_3/4) + \log I_1 + 2\log I_2$

The second and the third terms above are the amplitude of the fundamental signals w_1 and w_2 respectively.
If I_1 and I_2 are both increased by 1 dB, the levels of all third order intermodulation products are increased by 3 dB. However, if I_1 is kept constant and I_2 is increased by 1 dB, then w_a and w_b increases by 1 dB while w_c and w_d increases by 2 dB. Similarly, if I_2 is kept constant and I_1 is increased by 1 dB then w_a and w_b increases by 2 dB while w_c and w_d increases by 1 dB.

6.1.2 Theoretical bound for higher order non-linearity

Higher order non-linearity (5^{th}, 7^{th}, 9^{th}… order) can be treated in a similar way as in clause 6.1.1 equation 3.

5^{th} order non-linearity (a_1, $a_5 \neq 0$, $a_3 = 0$) leads to IM3 and IM5 products. In this case both IM3 and IM5 follow a 1 dB - 5 dB relation. In the standard case with 3^{rd} + 5^{th} order coefficients, the power dependency of IM3 products is determined by the coherent superposition of both effects. Therefore deviations from the 1 dB - 3 dB relations in both directions are possible. In any case, at sufficiently small power levels 3^{rd} order nonlinearity dominates the PIM results. Hyperbolic tangent or arc-tangent nonlinear functions with adapted coefficients are a possibility to approximate these effects.

6.1.3 Theoretical background for spread spectrum signals

In this clause the influence of modulation of carriers on the PIM result is investigated. Spread spectrum carriers were simulated by a multi tone signal which is a good approximation for LTE and WCDMA for PIM calculation. Analytical calculations for 3^{rd} and 5^{th} order as well as MatLab simulations predict an increase of PIM compared to the two tone CW scenario. This ''conversion factor' depends on the shape of the nonlinearity curve. For 3^{rd} order non-linearity the factor is exactly **3 dB** for infinite number of sub tones. This means that if a 2 × 43 dBm CW scenario is replaced by a 2 × 43 dBm spread spectrum scenario the power integrated over the whole IM3 BandWidth (BW) is doubled. For the 3^{rd} order nonlinearity, the IM3 bandwidth is three times higher than the carrier bandwidth. Simulation results are shown in Figure 6.2.3-1. For higher order nonlinearities, the IM3 bandwidth can extend even further.

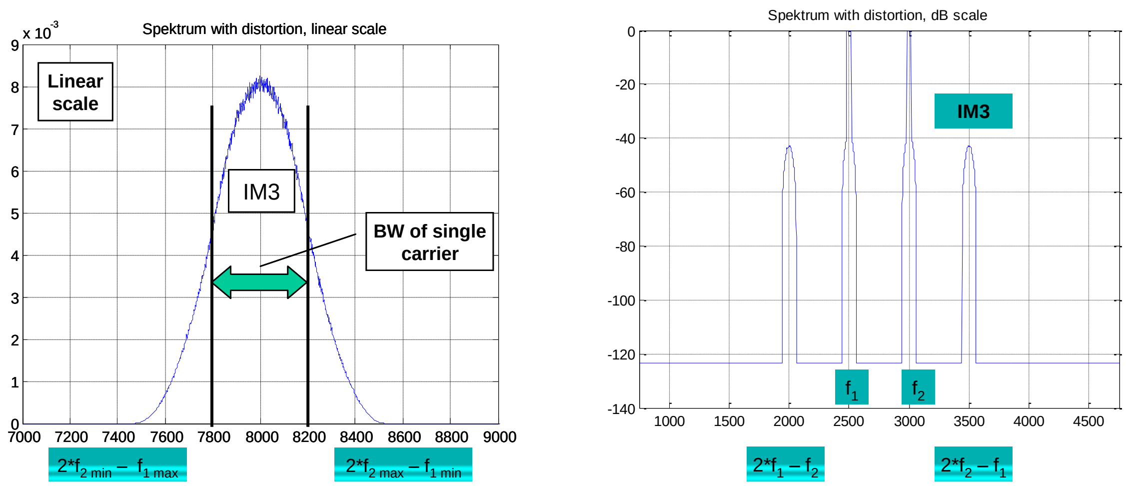

Figure 6.1.3-1: Matlab simulation: PIM of spread spectrum carrier for 3^{rd} order non-linearity

As the own receiver is the PIM victim, it is more realistic to integrate PIM power over carrier BW bandwidth only. For this definition the theoretical 3^{rd} order 'conversion factor' reduces to **1.8 dB**.

The reason for increased PIM for spread spectrum carriers compared to CW Carriers is an increased PAR (peak to average ratio) of modulated signals. This leads to the rule that reductions in the '1 dB - 3 dB relation' leads to a reduced 'conversion factor'.

6.2. Measurements

This clause shows measurement results for different intermodulation sources carried out by several companies.

6.2.1 Measurement configuration

A typical experimental setup used for high sensitivity two tone CW measurements and WCDMA measurements is shown in figure 6.2.1-1.

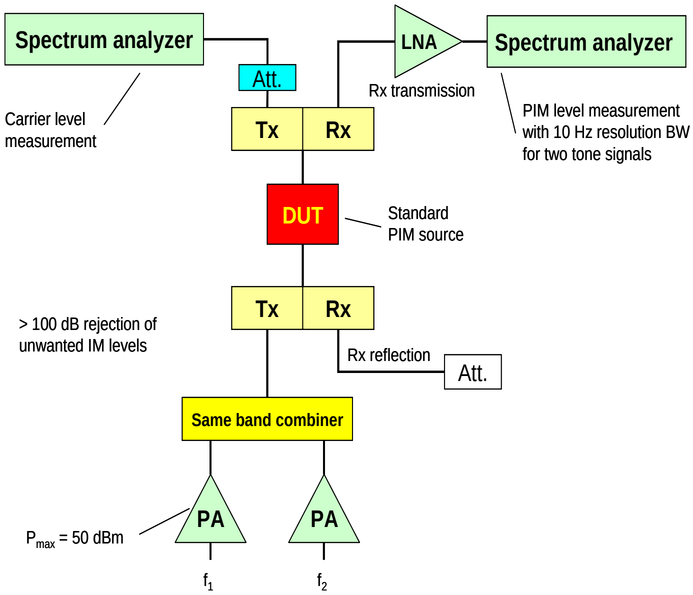

Figure 6.2.1-1: Setup for two tone CW and spread spectrum measurements

6.2.2 Two tone measurement results

Two tone Constant Wave (CW) measurements for different combinations of power levels of both carriers are reported in [6]. The PIM source used was a standard PIM source (IM3 = -80 dBm at 2 × 43 dBm). Results are shown in figures 6.2.2.1 to 6.2.2.-3. The solid line represents a theoretical 3rd order calculation. As expected these curves match very well to measured data for low carrier powers. At higher power levels (P_1 + P_2 > ~33 dBm), measured PIM levels are smaller than the simple 3rd order theory predicts. This indicates that the true 'conversion factor' for WCDMA will also be slightly lower than theory.

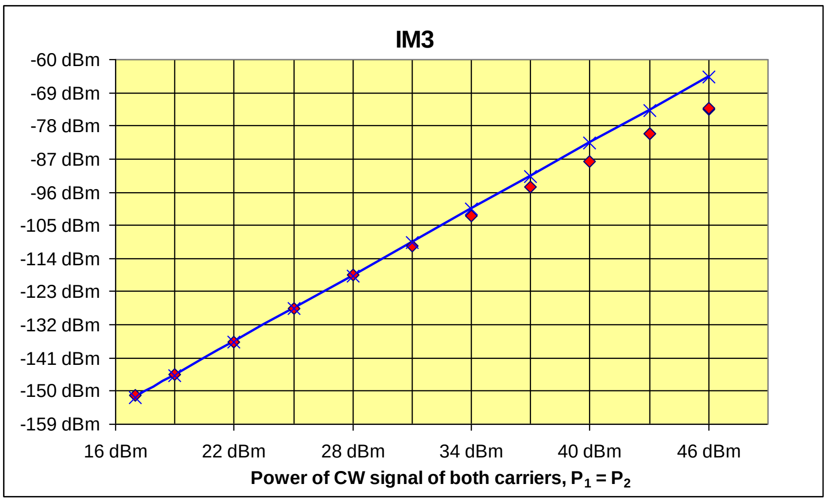

Figure 6.2.2-1: Measured IM3 levels compared to theory (solid line), variation of power for both CW signals P_1 = P_2

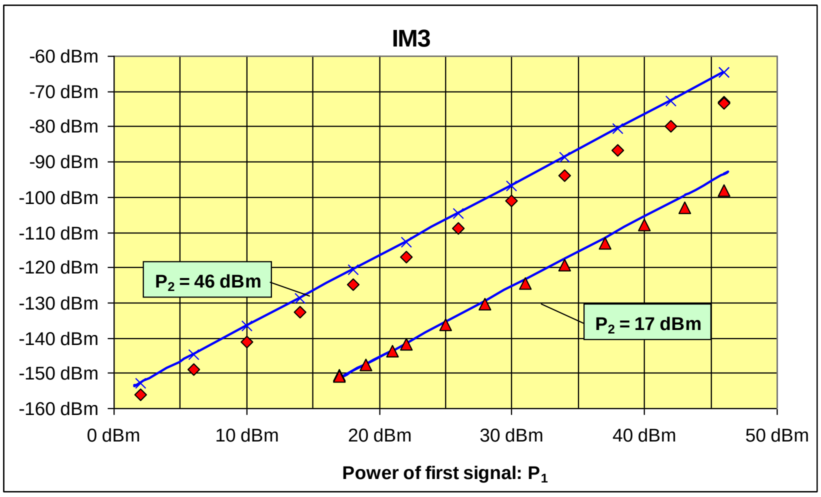

Figure 6.2.2-2: Measured IM3 levels compared to theory (solid line), variation of P_1 only, P_2 is fixed

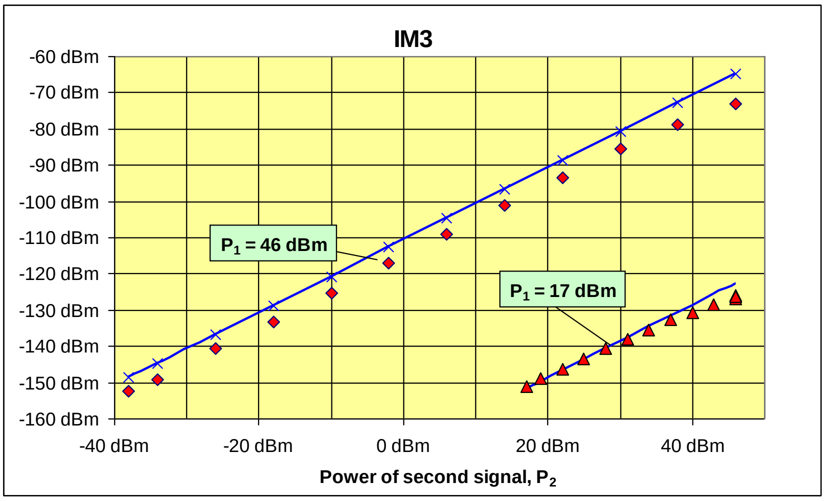

Figure 6.2.2-3: Measured IM3 levels compared to theory (solid line), variation of P_2 only, P_1 fixed

For IM5, the degradation of 1 dB - 5 dB relation, more pronounced than for IM3. The absolute levels of IM5 and IM7 are significantly lower than IM3 (measured: -37 dB for IM5 and -64 dB for IM7 at 2 x 43 dBm). The reported results can be generally accepted. Similar results are reported by Huawei and Kaelus [6]. Figure 6.2.2-4 shows a Kathrein measurement using specially prepared BS antennas.

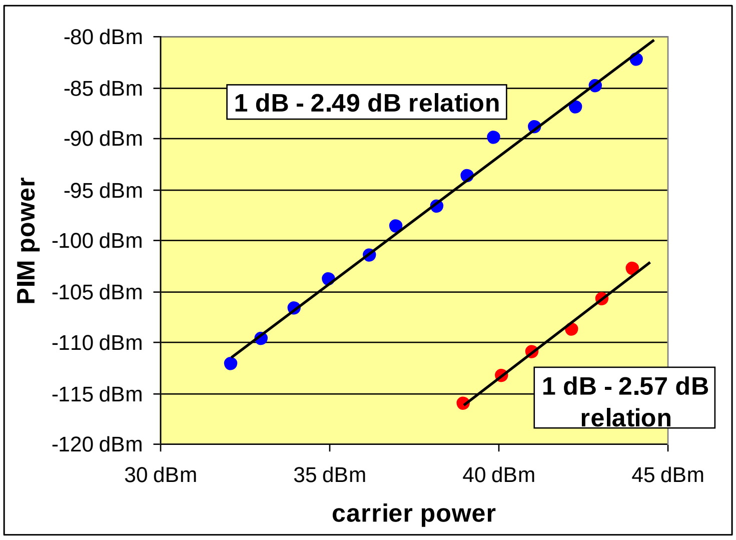

Figure 6.2.2-4: IM3 measurement of PIM for 2 differently prepared antennas

Huawei presented in figure 6.2.2-5 a 1 dB - 2.5 dB relation at 43 dBm. Kaelus investigated differently jumper cables and also measured comparable data (figure 6.2.2-6).

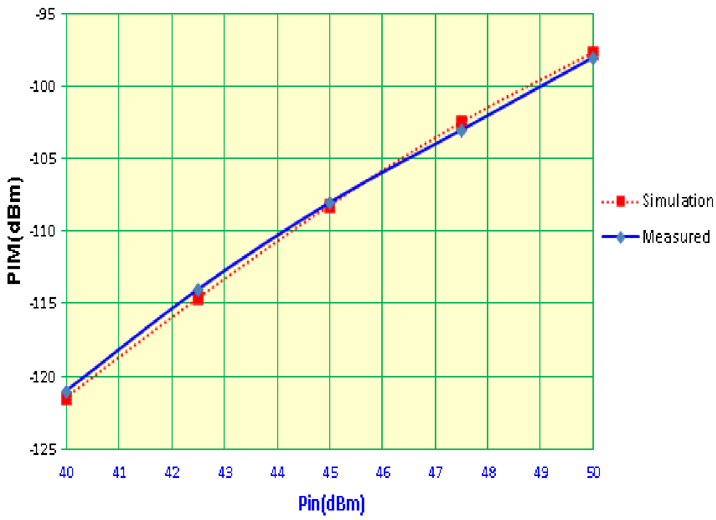

Figure 6.2.2-5: Simulation and Measured result of the PIM power vs. input power from Huawei

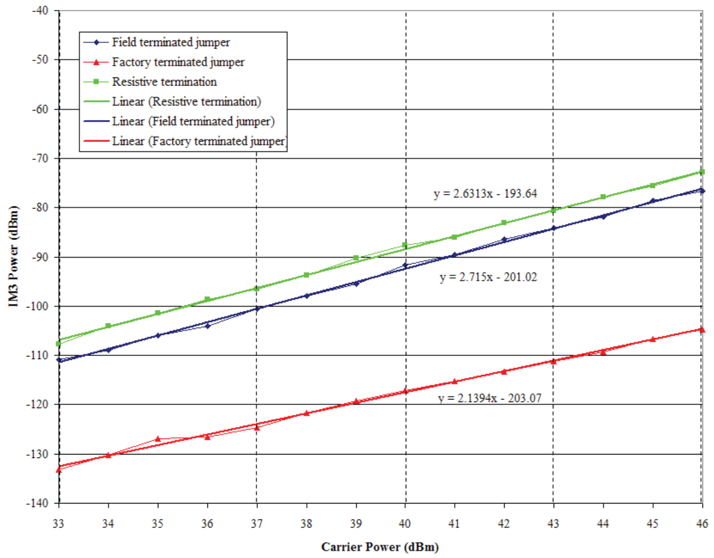

Figure 6.2.2-6: Measured IM3 power for jumper cables [6]

6.2.3 Spread spectrum measurement results

For comparison of spread spectrum signals with CW measurements, two Remote Radio Heads (RRH) were used in the measurement set up of figure 6.2.1-1. The RRHs could transmit either WCDMA or CW signals. A conversion factor of **1.7 dB** was observed for IM3 with an estimated measurement error of ±0.5 dB (figure 6.2.3-1). As expected, this result is lower than the theoretical values. The conversion factor for IM5 is 3.2 dB in accordance with a measured 1 dB - 3.7 dB power relationship [6].

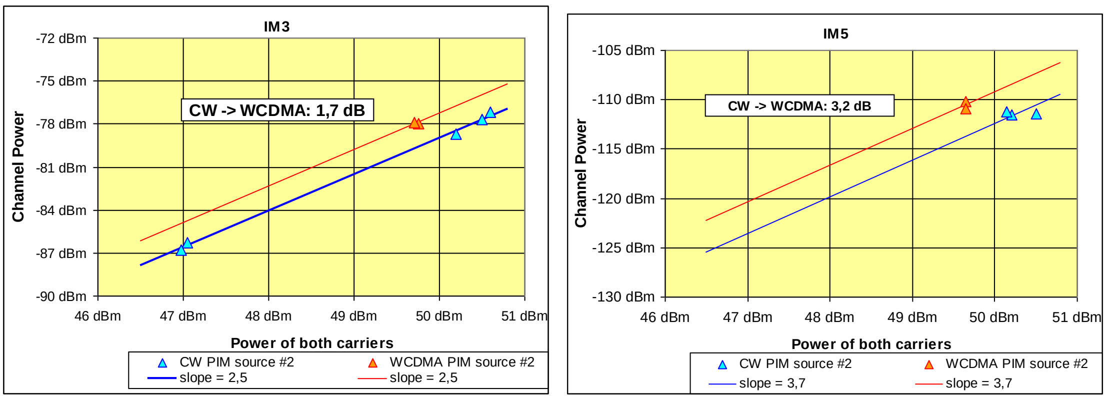

Figure 6.2.3-1: Conversion factor: Comparison WCDMA signal to CW signal

Changing the excitation source from CW to modulated signal (GSM/UMTS/LTE source), the simulation result is shown in figure 6.2.3-2 (Huawei).

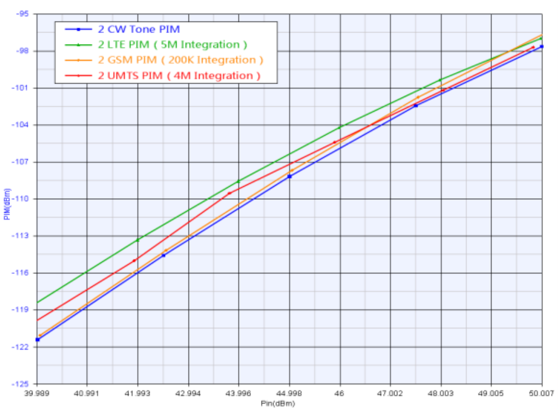

Figure 6.2.3-2: Simulation result of the PIM power vs. input power under different excitation from Huawei

Elaborate measurements are reported by Ericsson in [2]. A conversion factor of 2.1 dB is a reasonable assumption.

6.2.4 Measurement results for IM5 and IM7

This clause shows measurement results for IM5 and IM7 products. The measurement conditions are the same as for IM3 two tone signals.

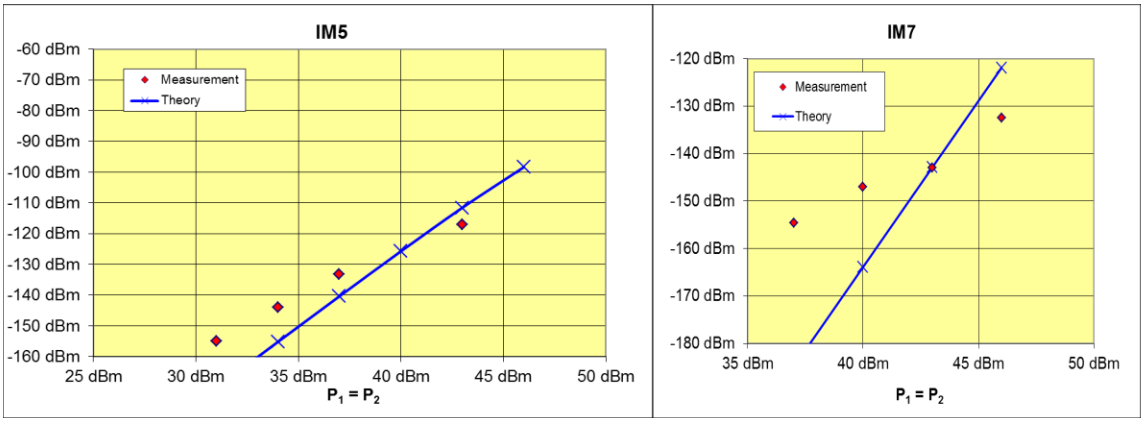

Figure 6.2.4-1: Measured IM5 and IM7 levels compared to theory (solid line), variation of power for both CW signals $P_1 = P_2$

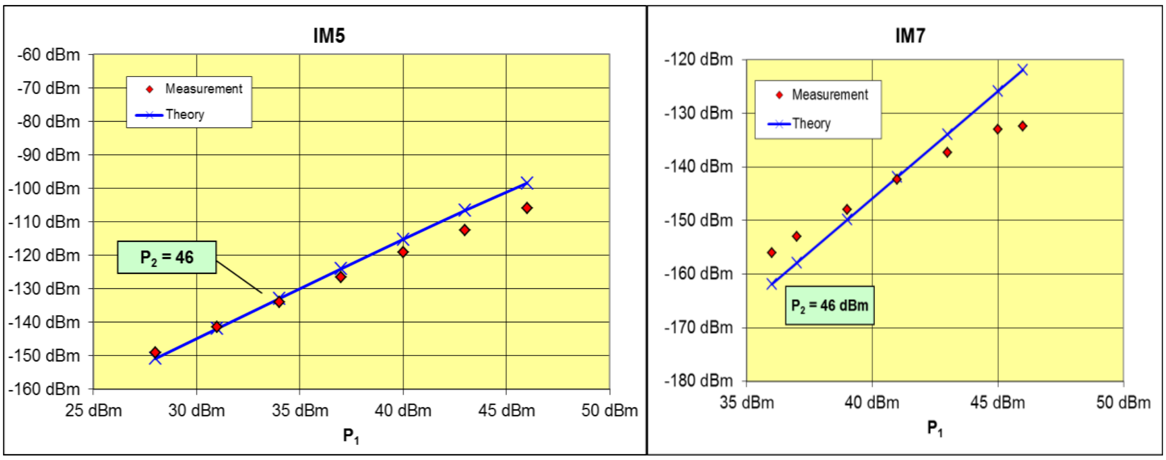

Figure 6.2.4-2: Measured IM5 and IM7 levels compared to theory (solid line), variation of P_1 only, P_2 is fixed

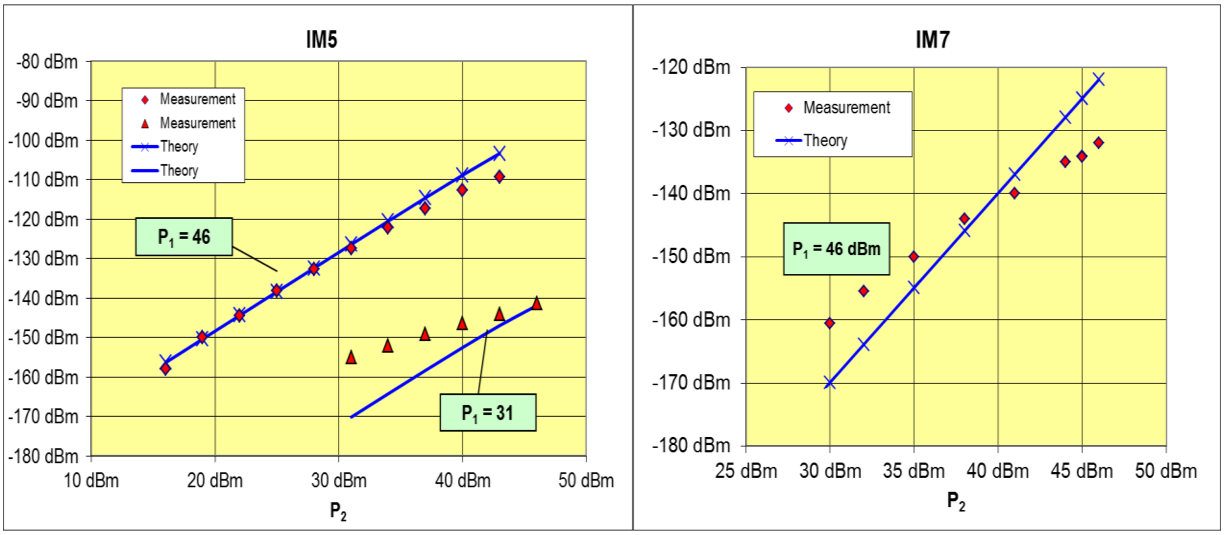

Figure 6.2.4-3: Measured IM5 and IM7 levels compared to theory (solid line), variation of P_2 only, P_1 fixed

The strength of the IM products depends on the source of the InterModulation (IM). Kathrein investigated antennas, combiners and connectors & cables.

The relation between IM3, IM5 and IM7 varied from 10 dB to 30 dB for different arrangements. These results are representative for antenna products.

The Taylor series as model for the nonlinearly behaviour leads to the result, that higher order IM products will increase faster with power than IM3. There will be expected the same level of higher order IM compared to IM3 at a certain high power. Nevertheless, Kathrein never observed this for real products.

The limits of measurement configuration did not allow signal strengths higher than 47 dBm per carrier (50 dBm in sum). However the curves suggest that there is a saturation. This is logical, as the sum power of all IM products cannot exceed the limit to the sum of the input power in contradiction to the unlimited theoretical Taylor model

6.2.5 Discussion of the measurement results

Comparison of theoretical results with several measurements showed that the theory explains the problem with sufficient precision.

The upper limit for a conversion factor is 3dB for 3rd order nonlinearity (PIM measurement BW = 3 times carrier BW). For the realistic case with the same BW for aggressor and victim, the conversion factor reduces from 3 dB to 1.8 dB. The conversion factor can be decreased by some tenths of dB for high power levels as measurements have showed. A conversion factor of 2.1 dB is a realistic assumption.

7 PIM impact on receiver performance

Considering the frequency domain relations for the generation of IM products, given the declared maximum RFBW and allocation of carriers, the IM3 products could potentially fall in own receive band as noise. For narrowband systems such as GSM, the IM products are also narrowband, while the IM products from wide band carriers or combination of wideband and narrowband carriers in multi-RAT operation will be broadband as shown in figure 7-1.

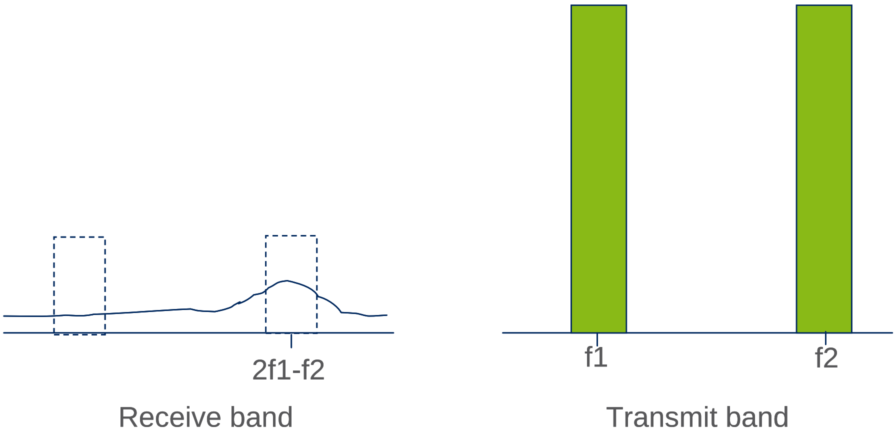

Figure 7-1: PIM impact on own receive band

To demonstrate a simple example calculation of possible PIM impact on reference sensitivity, we consider the following assumptions which apply to a Wide Area (WA) BS deployment:

- Carrier power 2 × 43 dBm UTRA carriers
- Receiver Noise figure: 5 dB
- A conversion factor of 2.1 dB to convert the CW to UTRA modulation.
  The conversion factor is a conservative average value based on empirical studies [2].
- Third order PIM performance of e.g. antenna: -150 dBc @ 2 × 43 dBm CW

Note that the conversion factor is an assumption used to derive the requirements and once the requirements are settled, the conversion factor in itself would have no further relevance. There would then be an agreed requirement that defines the PIM performance.

Based on the assumptions, the power of third order PIM products is 43-150= -107 dBm CW while the power of UTRA modulated PIM product would be -107 dBm + 2.1 dB (conversion factor) = -104.9 dBm/UTRA carrier BW.

Considering the noise floor of -103 dBm and the PIM level of -104.9 dBm (both normalized over a UTRA channel), the sensitivity degradation would be on the order of ~2 dB.

In order for the PIM level calculated above to occur, a scenario would be required where both carriers are transmitted at maximum level, frequency domain condition of centre frequency of the receiver that fulfils the criteria of 2f1-f2 MHz, and also operation of the BS in a band that would potentially suffer from PIM which makes this a kind of worst case scenario.

For lower carrier powers, it can be assumed that passive IM3 products increase or decrease by 3 dB when the carrier power is increased or decreased by 1 dB. A similar analogy can be used for higher carrier powers. Note that in practice, the PIM products do not strictly follow this theoretical behaviour, where both lower and higher ratios for the increase/decrease are regularly observed in practical measurements.

The third order passive intermodulation products have the highest level while for higher order intermodulation, the PIM level decreases and thus, the focus here is on the third order PIM.

Due to strong similarities between UTRA and E-UTRA waveforms, the conversion factor as well as calculations can be assumed to also apply to E-UTRA.

A reasonable level of PIM requirement on the BS (similar to levels defined for the antennas) is desirable, which in addition to other mitigation schemes should be sufficient to handle PIM if and when it occurs.

The above analysis applies to Wide-Area base stations based on typical power levels and IM performance of typical antenna and feeder systems. MR and LA deployments diverge from this discussion on the following points:

- Carrier power

  3GPP TS 25.104 [1] defines the Medium Range BS class as having a rated output power of ≤ +38 dBm, and a Local Area BS class as having a rated power of ≤ + 24 dBm.
  Similar classes are being defined in 3GPP TS 36.104 [2].

- Receiver noise figure

  Due to differences in their deployments, Medium-Range and Local-Area BS configurations are also specified with less sensitivity than Wide Area BSs. Corresponding values of noise figure for Medium-Range and Local-Area BSs are 10 and 14 dB respectively.

In consideration of these differences, conclusions reached for Wide-Area deployments are not directly applicable to Medium-Range and Local-Area deployments.

8 Deployment aspects and counter measures for PIM

8.1 Impact of site infrastructure

Although there is a large variation on what a site configurations may look like, it is still of interest to look into three main categories of site configurations as in figure 8.1-1.

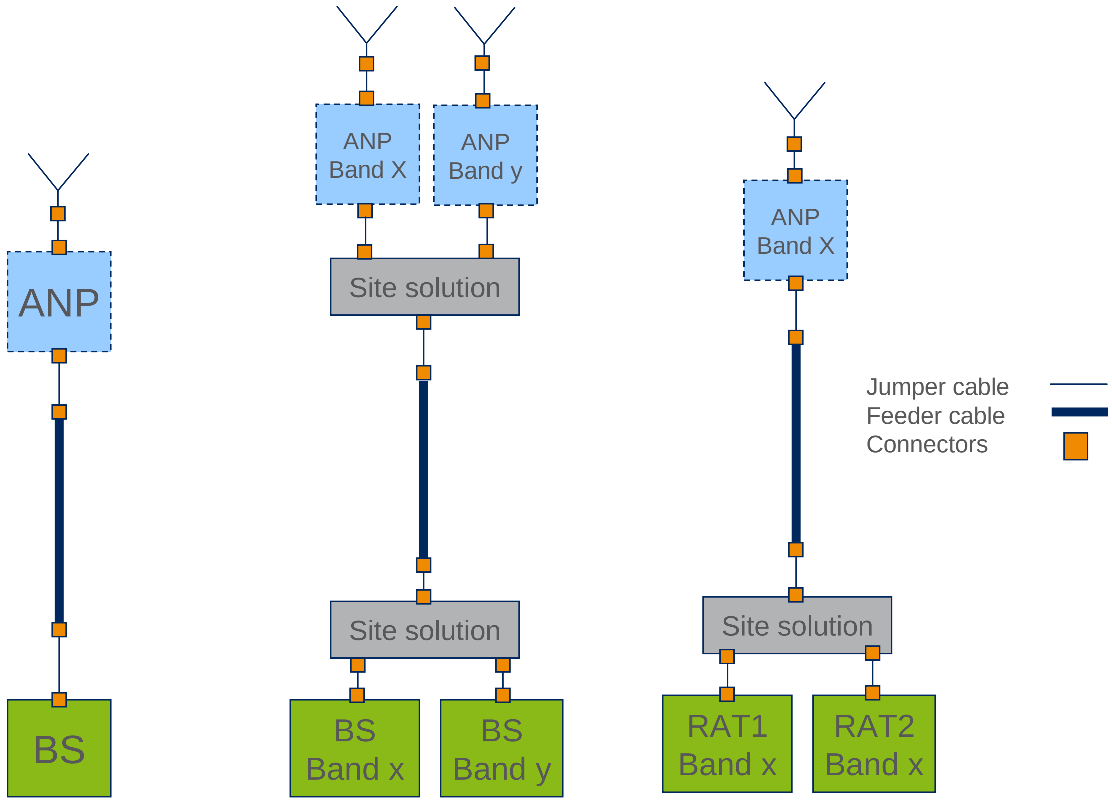

Figure 8.1-1: Logical schematic of some example site configurations

The figure on the left side is the simplest site configuration where the Antenna Near Parts (ANP) represents the possible low noise antenna amplifier etc. Note that not all sites would contain the ANP part.

The middle figure represents the scenarios where signals from base-stations handling two different bands are duplexed to one feeder and at the antenna separated by another diplexer to fully use the ANP part or other functionality such as different tilting per band etc.

The rightmost figure represents the scenario where two different RATs are mapped into both a common feeder and antenna. The site solution for this scenario is based on highly selective filters avoiding loss of spectrum or power.

Regardless of the site configurations, there are quite many elements in the site infra-structure such as jumpers, connectors, feeders, site solution filters, antennas etc. that can generate PIM and contribute to the total PIM interference experienced by the receiver. The PIM generated by all of these elements is assumed to be generated from the same transmitter signals. The resulting PIM products are therefore assumed to be correlated to some degree and may thus add in amplitude either constructively or destructively subject to the frequency-dependent phase differences and losses between the sources. It is thus important to consider the overall picture including also the BS PIM.

High quality site products are specified at PIM of at least ~150 dBc (@ 2x43 dBm CW) depending on type of component. There is however a large variation of site products as well as PIM performance which needs to be considered when discussing BS PIM requirements.

It should be noted that it is physically difficult to achieve PIM levels better than 150 dBc (@ 2x43 dBm CW) for any kind of products e.g. BS, antennas etc and thus there is a possibility that PIM is generated into receiver given the conditions stated in subclause 5.1 and 6. Further mitigations schemes might be needed to reduce the impact on receiver sensitivity. This is further discussed in subclause 8.2.

In cases where legacy deployments are re-used for a site where new RATs or operating bands are added by introducing multi-RAT or multiband base stations, replacement and/or update of site infrastructure elements as mentioned above may be required. Great care must then be taken, since unexpected PIM effects may come from the combination of old and new components together with the combination of different RATs such as GSM+LTE, which were not foreseen or accounted for in the original deployment.

8.2 PIM counter measures

In case the PIM occurs on some sites, there are some counter measures that can be deployed to reduce the impact. Some example counter measures are as following:

- High quality low PIM site infrastructure components: The lower the PIM level on site infra-structure components, the lower the impact.
- Reduced output power: Theoretically, the level of 3rd order PIM products would be reduced by 3 dB (both higher and lower values are regularly observed) for every dB reduction in output power.
- Tower-Mounted Amplifier (TMA) usage: The usage of low noise antenna amplifiers can reduce the impact of PIM caused by components on the BS side of the amplifier, thereby reducing the degradation in the receiver.
- Allocation and planning of carriers: This would affect the frequency domain criteria where third order PIM can be avoided. Note that higher order PIM has lower level than the third order.
- Separation of RX and TX signals: A separation of RX and TX signals (also applicable on antennas) would create high isolation and thus the PIM levels would linearly decrease with isolation.
- Separation of signals for different bands: A separation of the transmitter paths for different bands in case of multi-band transmission (also applicable on antennas) would create additional isolation and thus reduce the level of inter-band PIM components.

In some cases if needed a combination of counter measures such as above can be used to mitigate the impact of PIM.

8.3 Maintenance activities

Typically, resolution of a PIM problem will require a site visit by a technical crew. Maintenance activities can include site clean-up, disassembling and cleaning connections, reapplying weatherproofing materials, and replacement of damaged or defective components. The site cannot be in a fully-operational state during these activities. Operators want to minimize service disruptions, so these activities are either performed during periods of low activity (e.g., at night, on weekends) or they must be coordinated so that adjacent sites or co-sited equipment remains active.

Due to the difficulty of isolating site problems (including PIM-related problems), maintenance activities are often performed on a fixed schedule as determined by a model of site degradation. The maintenance activities might not actually be necessary, in which case the visit could have been delayed, or it is possible that a site needs attention before it is scheduled for maintenance. For these reasons, is desirable to monitor site performance so that maintenance activities can be performed on an as-needed basis.

9 New PIM-related RF requirements

Some important aspects to consider and derive new PIM related requirements are as follows:

- PIM products can be generated from the antenna port of the duplexer in the BS, through connectors, jumper cable, feeder cables, all site equipment including the antennas.
- PIM may occur in specific bands, given a certain declared maximum RFBW which would satisfy the frequency domain conditions for PIM.
- Since all components within site infrastructure contributes to PIM, it is important to have a proper BS PIM requirement, similar to high quality site equipment such as antennas.
- In the existing BS specification or conformance specifications, there are no requirements or tests defined to capture the performance of BS PIM. The existing requirements capture other aspects and would assume isolation of 30 dB between the transmitter and the receiver (e.g. emission requirements for protection of own or different BS).
- PIM can indirectly be measured as an additional reference sensitivity requirements. The existing requirements are unchanged. Such a measurement would cover both PIM and active IM.

NOTE 1: The proposed requirement is defined at the frequency of 3rd order PIM. Other orders of PIM components (higher order or 2nd order) are not covered by the present requirement.

For the possibility to set BS requirements for PIM, there are two options:

Option 1: The specifications remain as they are today without any additions.

This may not be the best option since the PIM performance of the BS would then remain unknown. Countermeasures can still be used to mitigate the impact but it would be difficult to choose proper counter measures if the BS PIM characteristic is unknown.

Option 2: Define relevant PIM requirements for the BS.

Since all components included in the site infrastructure would potentially contribute to PIM, the BS PIM requirements should be chosen on the same level as high quality site equipment such as antennas.
By defining proper and reasonable PIM requirements for the BS, the impact of the BS part would become predictable and proper counter measures could be more efficiently used.

Assuming that Option 2 is adopted, the minimum BS PIM performance should be equivalent to -150 dBc @ 2x43 dBm CW, similar to high quality antennas. Considering the need for generation of CW signals in the BS and the fact that PIM measurements usually are quite difficult, we would propose to introduce an indirect measure based on measuring the PIM sensitivity.

The indirect PIM sensitivity method is based re-calculating the -150 dBc @ 2x43 dBm CW to a noise level that can linearly be summed with the BS specified noise floor as further elaborated in sub-clause 7.
By setting up two modulated carriers (5 MHz UTRA or E-UTRA) with a frequency relation where a third order PIM product would hit a receive channel for measuring the receiver sensitivity of this particular channel, one indirectly measures and ensures that the PIM generated in the BS fulfils the required criteria.
The method is applicable in case there is a potential for 3rd order PIM interference into the own receiver, as identified in Table 5.2-2, otherwise the requirement is not applicable.

The indirect PIM sensitivity method is illustrated in figure 9-1.

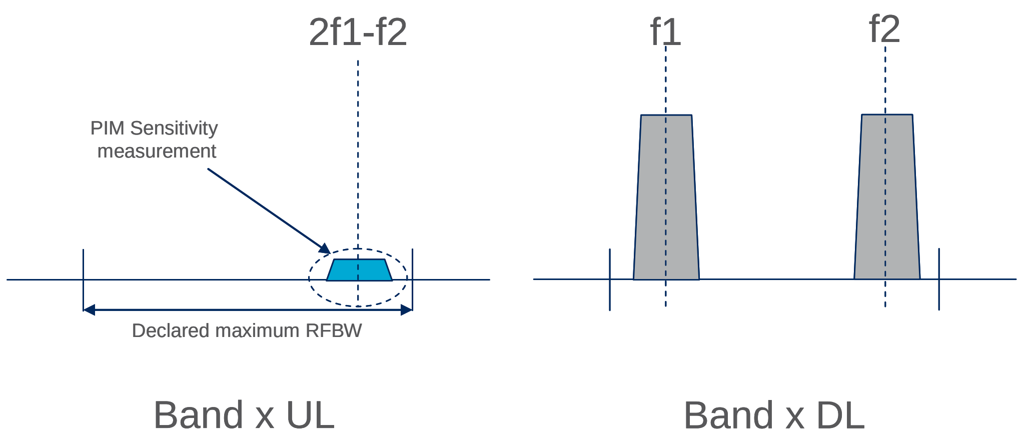

Figure 9-1: Visualization of indirect PIM sensitivity measurement

As an example, the indirect PIM sensitivity requirements for a wide area BS can be formulated as in Table 9-1, based on the PIM impact on reference sensitivity estimated in clause 7:

Table 9-1: Example Wide Area BS in-direct PIM sensitivity levels

Channel bandwidth [MHz]	Reference measurement channel	Indirect PIM sensitivity level [dBm] (note 2)
E-UTRA 1.4 (note 1)	FRC A1-1 in Annex A.1 in TS 36.104 [4]	[-106.8+2.2]
E-UTRA 3 (note 1)	FRC A1-2 in Annex A.1 in TS 36.104 [4]	[-103.0+2.2]
E-UTRA 5	FRC A1-3 in Annex A.1 in TS 36.104 [4]	[-101.5+2.2]
UTRA 5	According to A.1 in Annex A, TS 25.104 [3]	[-121+2.2]
NOTE 1: E-UTRA band widths of 1.4 MHz and 3 MHz can be used if the vendor declares no support for E-UTRA bandwidths of 5 MHz and larger. NOTE 2: The Indirect PIM sensitivity levels are based on calculation of 3rd order PIM only.		

The proposed approach also has the benefit that it captures all contributions from the BS, including the active IM. Note that the proposed new requirement does not affect any existing requirements, but is rather an addition to existing requirements.

NOTE 2: The requirement above is based an indirect measurement at the antenna connector. Assessment of PIM performance for other BS configurations (e.g., with an integrated antenna) may have a different requirement.

The proposed in-direct PIM sensitivity requirement would require a new test configuration enabling to generate a PIM product into own receive channel and it would consequently require additions to the conformance specifications. This is further discussed in clause 10.

10 Testing aspects

10.1 Measurement of PIM products in networks

10.1.1 External PIM test equipment

Test equipment for the measurement of PIM is available from a variety of vendors [2]. These devices typically employ a pair of sinusoidal signal generators combined via narrowband filters as a signal source and a high-sensitivity receiver for measuring the resulting PIM products. The signal generators are used to emulate BS transmitters, so the output power of each generator is typically close to 43 dBm. The narrowband filters are required to minimize internal intermodulation products.

PIM products become significant at levels below the noise floor of BS receivers. PIM testers must therefore very sensitive but at the same time exhibit excellent intermodulation performance so that PIM products from the system under test are not masked. PIM testers are often designed for portability as they are frequently used for on-site troubleshooting.

Care must be exercised in the use of external generators so that they do not contribute to the measured intermodulation. This includes calibration and proper connection to the system under test.

A limitation of external PIM testers is that they must be physically connected to the system under test. This disturbs the system under test in that connectors must be undone and the impedance of the tester is not likely to be identical to that of other elements of the system which are removed.

Going forward, antennas and feeder systems will be expected to maintain absolute PIM levels while carrying greater power. Existing testers typically provide excitation of 2 × 20 W. This will not be sufficient as multi-carrier and carrier aggregation systems which provide > 2 carriers become more common.

10.1.2 Integrated PIM measurement

BSs may provide integrated means for characterizing the PIM performance of antenna and feeder systems.
These systems maybe preferred over external systems as PIM is characterized with operational signal types and power levels in the system as installed. Integrated PIM measurement also has the advantage that it can be integrated with the product's alarm and monitoring system, so it can be invoked from a central maintenance site as-needed.

11 Summary and conclusion

Within the MSR-PIM study a range of issues and aspects has been discussed and concluded. The mechanisms behind PIM generation, deployment scenarios as well as counter measures were studied. It was also concluded that all equipment within the site infra-structure could potentially contribute to PIM.

To study the PIM impact on receiver performance, extensive discussion and empirical studies were performed to conclude on the conversion factor between CW and modulated signal and the wanted signal level. Evaluation examples of PIM impact on receiver performance were also provided.

Additional scenarios such as MB-MSR were also discussed, based on work items starting after the PIM study.

The main focus of the study concerned third order PIM products, discussions and empirical measurements on higher order PIM products were conducted, resulting in the conclusion that the third order PIM products have the highest level. In some bands the receive band can potentially get a direct hit from third order PIM, but there are other bands without third order PIM issues where there is a potential for higher order PIM products to hit the receiver.
There is therefore a need to also consider higher order PIM for these additional bands.

There is currently no test coverage in existing conformance specifications that captures the BS PIM performance. After long discussions on a possible new PIM sensitivity requirement, the need for this new requirement, the related testing and a possible requirement level, no consensus was reached on these aspects.

Annex A
Change history

Change history							
Date	**TSG #**	**TSG Doc.**	**CR**	**Rev**	**Subject/Comment**	**Old**	**New**
2012-03	R4#62bis	R4-122184			Report skeleton		0.0.1
2012-03	R4#62bis	R4-122828			Agreed Text Proposal in RAN4 #62bis: **R4-121842**, "TP for BS PIM study item objective"	0.0.1	0.1.0
2012-05	R4#63	R4-123787			Agreed Text Proposal in RAN4 #63: **R4-122383**, "for PIM TR: section 8, deployment aspects and counter measures for PIM" **R4-122384**, "TP for PIM TR: section 10, Testing aspects" **R4-123634**, "TP on Mechanism for PIM generation" **R4-123636**, "TP for BS PIM scenarios" **R4-123698**, "TP on PIM scenarios"	0.1.0	0.2.0
2012-08	R4#64	R4-125027			Agreed Text Proposal in RAN4 #64: **R4-124945**, "Discussion on multi-band scenarios" **R4-124971**, "TP on Impact of site infrastructure and counter measures"	0.2.0	0.3.0
2012-11	R4#65	R4-126081			Agreed Text Proposal in RAN4 #64bis: **R4-125532**, "TP on PIM impact on reference sensitivity" **R4-126006**, "TP for TR 37.808: Adding PIM scenario for FDD/TDD BSs collocated and using the same antenna system"	0.3.0	0.4.0
2013-01	R4#66	R4-130382			Agreed Text Proposal in RAN4 #65: **R4-126920**, "TP on Section 6.2. Measurements results for a conversion factor between CW-carriers and modulated carriers" **R4-126921**, "PIM in Local Area and Medium Range BS deployments" **R4-126922**, "TP on PIM requirement for BS"	0.4.0	0.5.0
2013-04	R4#66bis	R4-131512			Agreed Text Proposal in RAN4 #66: **R4-130511**, "TP: PIM Measurement results for IM5 and IM7"	0.5.0	0.6.0
2013-05	R4#67	R4-132237			Agreed Text Proposal in RAN4 #66bis: **R4-131990**, "TP for TR 37.808: LTE single-band higher-order PIM measurement results"	0.6.0	0.7.0
2013-08	R4#68	R4-133946			Agreed Text Proposal in RAN4 #67: **R4-133096**, "Addition of PIM from Multiple Sources"	0.7.0	0.8.0
2013-08	R4#68	R4-134573			Agreed Text Proposal in RAN4 #68: **R4-134529**, "Text Proposal for PIM study item conclusions" **R4-134530**, "TP for PIM counter measures"	0.8.0	0.9.0
2013-09	RP#61	RP-131140			Submission to TSG RAN#61 for 1-step approval	0.9.0	1.0.0