



## Passive Intermodulation Distortion in Triband Antenna Systems

Zidong Liu

email: zidong.liu@csa-wireless.com

### 1. Introduction

Interference is a critical factor in the performance of cellular communications systems. One of the interference sources is the passive intermodulation (PIM) generated by a base station antenna. In cellular systems, base station antennas are often used for transmission and reception at the same time. When two or more transmitter carriers are combined in an antenna, new signals, i.e. intermodulation products, are generated. If one of those signals falls within the receive band, it could de-sensitise the receiver, and cause bad quality calls or even dropped calls. In this paper, the intermodulation distortion generated in the tri-band antenna system is discussed, and the solutions to minimise the interference are suggested.

### 2. Triband Cellular System

As the demand for the cellular services increases, more systems have been introduced into the market. Currently there are multiple frequencies in use globally; AMPS 800, GSM900, PCN (GSM1800), PCS 1900 and UMTS. It is becoming hard to find suitable sites for base stations, and even harder to get approval from the planning authorities due to increasing resistance from local residents. As a result, co-locating multiple antenna systems into one site is an attractive solution. Due to tower loading and lease costs, a multi-band antenna can be a good solution to address this situation. However, in any co-located site, the carrier frequencies have to be carefully planned to avoid the inter-band intermodulation interference, particularly the lower orders of intermodulation products because they usually have much larger magnitudes than higher-order products. Table 1 shows some of the lower order intermodulation products in a triband system. In addition to the single-band intermodulation products, new 2<sup>nd</sup> order PIM products generated by mixing the GSM900 and PCN carriers fall within the GSM900 receive band. 3<sup>rd</sup> order and a 4<sup>th</sup> order intermodulation products of the same carrier frequencies fall within the UMTS band. Thus, it is easy to see that PIM products need to be addressed to avoid inter-band interference and deleterious effects on the network quality.

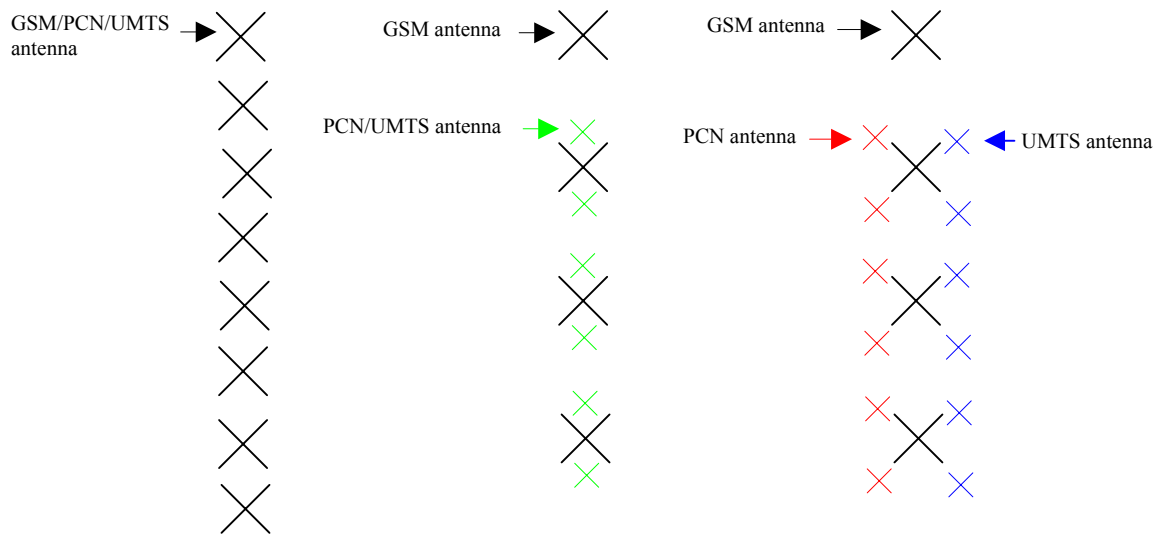
**Table 1 - Lower order PIM products in a triband system**

	Intermodulation products
GSM900	3 <sup>rd</sup> order in GSM900 (2×GSM900 TX – 1×GSM900 TX)
PCN	3 <sup>rd</sup> order in PCN (2×PCN TX – 1×PCN TX)
UMTS	7 <sup>th</sup> order in UMTS (4×UMTS TX – 3× UMTS TX)
Triband system GSM900, PCN, UMTS	2 <sup>nd</sup> order in GSM900 (1×PCN TX – 1×GSM900 TX)
	4 <sup>th</sup> order in UMTS (3×GSM900 TX-1×GSM900 TX)
	3 <sup>rd</sup> order in UMTS (2×PCN TX-1×PCN TX)

### 3. Triband Antenna

To achieve lower PIM levels, every step from design to production must be planned with this in mind. First, poor mechanical junctions must be avoided. Second, only materials with low PIM generation levels can be used. Finally, contamination must be avoided during material processing and antenna assembly. In addition, triband antennas present a special set of challenges. The antennas must be designed in such a way so that the isolation among all three bands is high enough to minimise inter-band intermodulation distortion. For example, if a wide-band antenna is used to cover both the PCN and UMTS bands, the 3<sup>rd</sup> order intermodulation product generated by mixing two carriers in the PCN band will directly fall within the UMTS receive band. However, if two single-band antennas with an isolation of 45dB are used to cover each band, PIM will be reduced by 45dB, provided the single-band and wide-band antennas have the same PIM level.

Figure1 shows three triband antenna configurations. The first two use wide band radiating elements to cover more than one band. As we have discussed before, the wide band structure will result in the higher inter-band PIM distortion due to the lack of inter-band isolation. The third configuration avoided using any wide band radiating elements. However, asymmetry in the design not only reduces the inter-band isolation but also results in the azimuth pattern squint in the PCN and UMTS bands.



**Figure1 - Three triband antenna configurations**

CSA has addressed this problem by engineering a unique symmetrical antenna structure which avoids the pitfalls from the structures shown in Figure 1. In this structure, three separate antennas are used, one for each band. This yields high isolation among all three bands. It should be emphasized that the higher isolation achieved by inserting filters into the antenna input ports does not help to reduce the inter-band interference distortion because PIM generated in the antenna system within the receive frequency bands cannot be filtered out.

In addition to excellent isolation, the separate structure allows different elevation beam tilts to be used if needed. With the symmetrical antenna structure, excellent performance results, including good tracking of the azimuth radiation patterns without beam squint. Furthermore, the antenna is no larger than a single band GSM900 antenna!

#### **4. Non-Antenna Related Passive Intermodulation Distortion**

While antenna design is a critical part of PIM management, it must be noted that other elements of the network can introduce PIM problems. Base station antennas are generally mounted on steel structures. A small part of the signal radiated from the antenna will illuminate the structure and PIMs generated in the structure will couple back to the antenna. If non-linear metallic objects, such as rusty bolts and nuts, and other metal-to-metal joints exist in the structure, it is very likely that the significant intermodulation distortion could be generated by those objects, although the antenna PIM was low on its own. Using single-pole or welded structures rather than lattice structures is helpful and good site maintenance is needed to avoid potential PIM sources.

#### **5. Conclusion**

Intermodulation interference is a major issue for the cellular communication systems, particularly for multi-band systems. PIM products are generated at any inter-metallic joint, and a loose nut or a rusty connector could dramatically change the PIM level. Unfortunately there isn't a magic wand to solve this problem. The systematic approach, such as to avoid the lower order of intermodulation products falling within the relevant receiving band, to use high quality antennas, and to keep the sites away from the non-linear metallic objects are the only way to control the intermodulation interference in a cellular system. At CSA, a great effort from design to production has been made to achieve lower intermodulation levels. Using unique symmetrical designs, CSA has developed triband antennas that not only have excellent PIM performance, but also offer uncompromised performance in terms of size and RF performance.

CSA Wireless,  
Europe/ Asia-Pacific:  
Knight Road, Rochester, Kent, ME2 2AX, UK  
+44 (0) 1634 735 544

Americas:  
1500 Prodelin Drive, Newton, NC 28658, USA  
+1 828 466-0412

[www.csa-wireless.com](http://www.csa-wireless.com)