NANOCELLS INTRASYSTEM INTERFERENCE REALISTIC WORST CASE ANALYSIS FOR OPEN SITE PERSONAL COMMUNICATION SCENARIOS

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ABSTRACT

The exponential growth in mobile communications is followed by the development of new generations of Personal Communication Systems (PCS). Numerous research activities and papers have been published on PCS but only a few deal with the Electromagnetic Interference (EMI) affecting those systems. This paper presents a realistic worst case analysis and computation of the PCS intrasystem interference effects on open site nanocell scenarios. The operation range is up to 200m, usually under Line of Sight (LOS) propagation conditions where intrasystem interfering signals are maximum. Analysis and computation results are provided for a typical second generation cordless PCS CT-2 telephone (telepoint) operating in the 900 MHz frequency band. The computations show that for most cases of nanocell open site, intrasystem interference can be neglected, except for a few cases of single tone spurious. The good performances is due to PCS advanced Digital Signal Processing (DSP) technology advantages using Adaptive Power Control (APC) to optimize transmitter power requirements and to Dynamic Channel Assignment (DCA) electing the best signal to noise and interference channel available.

I. Introduction

The exponential growth in mobile communications has led to the development of numerous new Short Range Distance (SRD) systems which are coming into widespread commercial use [1]. The interest in investigating the Personal Communication System immunity to interference, especially for spectrum utilization purposes has increased significantly [2]. Thus this paper investigates the intrasystem mutual interference effects in PCS cells operating in open sites (outdoor conditions). A nanocell network represents a cell under open site propagation conditions with a maximum operation range of 200 meters, in comparison with the significantly wider operation ranges of common cellular radio systems [3,4].

Figure 1 shows an open site nanocell radio system, where some wireless users operate simultaneously at a radius of up to 200m from a common base station connected by wires to a central telephone network. Hence, the problem of mutual radio intrasystem interference between the users' and the base stations' radio becomes an important issue [5,6]. Improving PCS system operation quality requires an analysis and computation of Signal to Noise and of Interference to Noise Ratios (SNR), (SIR) and bit error rate probability for the influent mutual interference sources. This analysis is important especially for PCS open site scenarios where the base and handset antennas are usually in Line of Sight (LOS) Free Space

(FS) propagation conditions, [7] and the interfering power levels are significantly higher than for indoor situations [3;8].

The analysis and computation method described provides a means to reduce interference effects by improving site management criteria and system mitigation techniques. Quantitative computations introduced for the expected desired signal and interference power levels are correct for CT-2 PCS systems operating under an open site nanocell scenario. A CT-2 Common Air Interface (CAI) telepoint system was used as an example, which represents a typical PCS of the second generation [9]. The CT-2 is one of the earliest digital PCS systems introduced using efficient DSP techniques discussed in the following chapters. However, the CT-2 system, first introduced in the United Kingdom, is still very popular in several Far East countries. For instance, the September 1998 (P.161) edition of the IEEE Communication Magazine mention that for South Korea , in spite of the great success of CDMA technology, there are still more than 400,000 subscribers using the CT-2 system in the frequency range of 910 to 914 MHz. The analysis and computation method presented for intra-system interference can also be applied to the Digital European Cordless Telecommunication (DECT) system which is used extensively in Europe and in several other countries in the world or any present or future PCS under nano-cell propagation conditions. In this paper the desired received power level computation for an outdoor nanocell system is introduced in Section. II, followed by the main intrasystem mutual interference sources analysis and computation given in Section III. Section IV and Appendix A provide the main conclusions of the investigations.

II. Nanocell system receiver desired power levels

A CT-2 PCS telepoint system, was chosen for demonstrating the receiver desired power level computation method [3, 4, 5, 7] required to achieve the desired signal to noise and interference ratio and error probability. The desired power level at the victim receiver preamplifier following the antenna input as shown in (Figure 2) is calculated using the well known Friis equation for Line of Sight (LOS) Free Space (FS) Propagation conditions.

$$P_r = P_t.G_t.G_r.\left(\frac{\lambda}{4\pi d}\right)^2.\frac{1}{A_b} \tag{1}$$

where

$$\lambda = \frac{c}{f_0} \tag{2}$$

and

$$A_{fs} = \left(\frac{4\pi d}{\lambda}\right)^2 \tag{3}$$

or more convenient for radio system specialists in logarithmic units,

$$P_R = P_T + G_T - A_B + G_R - A_{FS} \tag{4}$$

where

P_R - is the received input power level in dBm

P_T - is the transmitter output power level in dBm

A_B - is the additional equipment front end losses including the human body (1 to 2 dB) in the 900 MHz frequency band

h - is the headset height (about 1.5m)

G_T - is the transmitter antenna gain (appx. 3 dBi maximum)

G_R - is the receiver antenna gain in dBi (appx. 2 dBi maximum

A_{FS} - is the free space propagation dispersion loss in dB [7] and is computed as

$$A_{FS} = 10 \cdot \log\left(\frac{4\pi d f_0}{c}\right)^2 = -27.5 + 20\log f_0 + 20\log d \tag{5}$$

where c is the velocity of light , f_0 is the carrier frequency in MHz and d is the separation distance in meters between the system transmitter and receiver antennas as shown in Fig. 2. Required system transmitter and receiver parameters are presented in Appendix A. The scenario for free space propagation loss conditions is introduced in Figure 2. In the case of line of sight conditions, no complex near field propagation effects will occur. For our scenario, the minimum distance ***d*** between all system handset antennas and the base station is $d_f \geq 3\lambda$, which exceeds 3m, and for the non-directive monopulse or heliax antennas that are used for headsets, the distance is less than 1m at of 900MHz. Therefore, for a distance of $d_f \geq 3$m, simple far field propagation conditions are certainly valid [11; 12].
Flat earth approximation is applied and if LOS path clearance occurs, the free space propagation equation is valid. The path clearance depends on the 1st Fresnel zone clearance or obstruction as shown in Figure 2. From propagation principles the classical Friis equation can be applied when dispersion attenuation is proportional to the square of the distance if more than 60% of the 1st Fresnel zone ellipsoid is clear of obstacles [7;13].

The 1st Fresnel zone radius $F_{ZR_{(1)}}$ is given by

$$F_{ZR_{(1)}} = 17.3\sqrt{\frac{d}{4f_0}}. \tag{6}$$

where the distances d, and $F_{ZR_{(1)}}$, are in meters and the frequency, f_0, is in MHz. The maximum radius of the 1st Fresnel zone is located at $\frac{d}{2}$ and h_m is the antenna height at half distance between the base and handset positions as shown in Figure 2. Most cases of open site nanocell PCS under LOS propagation conditions, will be characterized by the clearance of more than 60 % of the 1st Fresnel zone [7]. Therefore for our scenario the free space propagation equation usually applies resulting in a propagation loss, A_{FS} [8].

For f_0 = 900 MHz, equation (5) yields :

$$A_{FS} \approx 31.6 + 20\log(d) \tag{7}$$

The propagation dispersion loss shown in equation (7) for different operation distances and antenna height are presented in Table 1; $\mathbf{h}_b$ and $\mathbf{h}_h$ are the median height of the base station and the portable CT-2 antennas, respectively. The results of P_R in dBm for P_T = 10 dBm, are also included. At distances less than 100 m the applied Adaptive Power Control (APC) mechanism decreases P_T to less than 4 dBm [4]. For the quasi LOS open site nanocell scenario the desired receiver power is Rician statistically distributed and the initial SNR is high [15,16]. The received signal level must exceed the receiver input noise level in order to achieve an acceptable error probability.

Table 1 : Worst case desired power levels and path clearance for typical open site scenarios (f_0 = 900 MHz)

h_b (m)	h_h (m)	d (m)	h_m (m)	$F_{ZR_{(1)}}$ (m)	Path clearance of the 1st Fresnel zone	A_{FS} (dB)	P_R (dBm)
3	1.2	200	2.10	4.1	more than 60%	77.5	-65
5	1.5	200	3.25	4.1	more than 80%	77.5	-65
7	1.8	200	4.40	4.1	complete clearance	77.5	-65
3	1.2	100	2.10	2.9	more than 80%	71.5	-59
5	1.5	100	3.25	2.9	complete clearance	71.5	-59
3	1.2	50	2.10	2.05	complete clearance	65.5	-53

The equivalent receiver input noise P_n at ambient temperature conditions is:

$$P_n = K \cdot T_a \cdot B_r \cdot F_r \tag{8}$$

where $KT_a \simeq -174(\text{dBm/Hz})$ at room ambient temperature, B_r is the receiver IF bandwidth in Hz, the specified receiver internal noise figure F_r (worst case of 10 dB [5]), and $B_n = 84\,\text{kHz}$. Thus, the receiver input noise power level in logarithmic units is:

$$P_n = -174(\text{dBm/Hz}) + 10\log(84 \cdot 10^3) + 10 = -114.8\text{dBm} \tag{9}$$

Median values of the average ambient noise figure F_a above the $K \cdot T_a \cdot B_r$ power level expected near the ground as function of the radio frequency range can be obtained from Consultative Committee International Radio (CCIR) graphs [17]. For 900 MHz , in suburban areas, we obtain $F_A \simeq 1dB$ and in urban areas $F_A \simeq 15dB$ or F_A= antilog 1.5 $\simeq$31.6 [7;17].

The equivalent system noise figure is equal to:

$$F_{eq} = F_r + s_a F_a \tag{10}$$

where s_a represents the antenna efficiency, which is around 0.5 [20]. Hence, $F_{Eq} \approx F_R \approx 10dB$ in suburban areas, and in urban areas $F_{Eq} = 10\log(10 + 0.5 \cdot 31.6) \simeq 14.1\text{dB}$. Using a Non-coherent Binary Frequency Shift Keying (NCFSK) modulation technique, a $\text{BER of } 10^{-3}$ or less required a SNR $\geq$11dB and when fading is added a SNR$\geq$16dB [11; 18]. Thus, the received power level input P_R required to achieve BER$\leq 10^{-3}$ is, from equations 9 and 10, $P_R \geqq$ - 98 dBm in suburban areas and $P_R \geqq$ 94 dBm in urban areas [18].

III. Main intrasystem mutual interference sources

The main mutual intrasystem interference sources shown in Figure 3 affecting the PCS system are : adjacent linear interference, receiver and transmitter intermodulation (IM), single tone spurious (STS) and desensitization. A discussion and computation of these interference sources effects are presented in this section.

1. Intrasystem adjacent linear interference effects

For several handsets operating simultaneously at the same PCS site, cochannel and adjacent channel interference is excluded due to the system receiver dynamic channel selection process [6;9]. When a handset operates on a frequency, f_0, a proximate adjacent channel $f_0 \pm \Delta f$ cannot be attributed to a new handset if the new base receiver spurious input power, P_{R_s} exceeds –89 dBm. As the signal from the operating handset transmitter contributes to P_{R_1}, several adjacent channels will not be allocated. The number can be obtained from the system transmitter power spectrum response, presented in Figure 4 and from the distance d between the operating handset transceiver and the base station antennas.

2. Receiver intermodulation (IM) power level

IM product frequencies may penetrate the selective Intermediate Frequency (IF) filters and disturb PCS system operation [14]. Any 2nd or other even order IM products at frequencies $|f_1 \pm f_2|$ cannot affect the system receivers due to the PCS system selectivity and the narrow frequency band from 891 to 895 MHz. If the interfering frequencies are f_1= 892 MHz and f_2= 893 MHz, the 2nd order IM frequencies are 1 MHz, and 1785 MHz which are not in the receiver passband. The 3rd order IM products, however, may affect the receiver. A realistic worst case scenario for 3rd order receiver IM is when the victim receiver is tuned to $f_0 = 894.0MHz$, for instance. At distances for $d \geq 3m$ when two handsets are transmitting simultaneously at adjacent channel frequencies $f_1 = (f_0 - \Delta f)$ and $f_2 = (f_0 - 2\Delta f)$, the preamplifier nearest 3rd IM output frequency products are equal to the desired frequency

$$f_{IM_{31}} = 2f_1 - f_2 = f_0 \tag{11}$$

$$f_{IM32} = 2f_2 - f_1 = f_0 - 3\Delta f \tag{12}$$

This interfering signal will reach the detector stage directly without any filtering frequency dependant attenuation. The scenario results in a most proximate IM adjacent channel frequency of $\Delta f = 0.3$MHz due to the system dynamic channel selection process. The interfering preamplifier power level input P_{Ri} in logarithmic units, is equal to

$$P_{R_i} = P_{T_i} + G_T - A_{FS} + G_R - A_s, \tag{13}$$

if we refer to equation (4) where

$$A_s = A_B + A_{\Delta f}. \tag{14}$$

Thus, the frequency of worst case interfering signal near to the base station is where $P_T \leq 0$dBm due to the system DSP power control process. $A_{FS} \simeq 41dB$ from equations (4) and (7), as d_{min} = 3m, $A_B = 2dB$, $G_T + G_R = 5dBi$ and $A_{\Delta f} = 5dB$. Therefore the realistic worst case receiver pre-selector filter circuit input power level obtained is $P_{Ri1} \leqq -43dBm$.

The second worst case interfering frequency is: $f_2 = (f_0 - 0.6)$ MHz and $P_{Ri2} = -58dBm$ because of the filter attenuation $A_{(2\Delta f)} \approx 15dB$ at the second adjacent channel for a 0.6 MHz frequency interval.

The 3rd order IM product highest power level at the preamplifier stage output can be computed from the following equation [10;20].

$$P_{IM_{3h}} = 3P_{f1} - 2P_{IP_3} - \Delta P_i \tag{15}$$

where $P_{f1} = P_{Ri1}$ and $P_{f2} = P_{Ri2}$ represent the two interfering worst case power levels at the input of the victim receiver. $\Delta P_i = P_{f1} - P_{f2}$ and $P_{IP_3} = -22\,\text{dBm}$ is the receiver specified 3rd order intercept point power level [6,7]. Thus, the computed interfering $P_{IM_{3h}} \simeq -100dBm$ and $P_{IM3\ell} \simeq -115$ dBm are significantly lower than the desired power level around –65 dBm as shown in Table 1. Therefore the P_{IM_3} products will not disturb the CT-2 receiver operation and only can cause tedious, not real, interference when the desired signal is absent. The higher odd order IM products that can produce in-band IM interference to the victim Rx, especially the 5th order, generate significantly less P_{IM5} power level than the 3rd order. Thus, their interfering effects can also be neglected [14].

3. Transmitter intermodulation product power levels

Transmitter IM products are due to the simultaneous operation of two or more transmitters. Signals radiated by the two transmitters' antennas may cause co-channel or adjacent channel interference to a system receiver tuned to the IM product frequencies generated in the transmitters [14]. A typical transmitter IM scenario is presented in Figure 5.

For the realistic worst case scenario of a base station transmitter Tx radiating at frequency f_1 simultaneously with a mobile handset transmitter at frequency f_2. The minimal distance between the two handset transmitter antennas is also $d_r = 3\text{m}$ and the minimal frequency interval Δf between the two transmitters exceeds 0.3 MHz. If, for realistic worst case conditions we choose the base and the handset frequencies $f_1 = 893.0\text{MHz}$ and $f_2 = 893.3\,\text{MHz}$, using equation (11) and (12) , the 3rd power IM product frequencies in the base station transmitter are $f_{IM_h} = 892.7$ MHz at a higher power level and $f_{1M\ell} = 893.6MHz$ at a lower power level.

From the transmitter IM scenario shown in Figure 5 $P_{f_1} = P_{f_2} = 0dBm$ due to the base adaptive power control process $A_{FS} = 41dB$ at $d = 3\text{m}$ from the handset as shown from equation 7 when $P_{f1,2} \leqq -41dBm$ and the specified power amplifier 3rd order intercept point $P_{IP_3} = 30\text{dBm}$. We can compute the 3rd order IM products at the power amplifier output of the 1st base station transmitter [16;19] using the following equations [7, 14].

$$P_{IM_{3h}} = 2\left(P_{f_1} - P_{IP_3}\right) + P_{f_{1,2}} \tag{16}$$

and

$$P_{IM_{3\ell}} = 2\left(P_{f_{1,2}} - P_{IP_3}\right) + P_{f_2} \tag{17}$$

Therefore $P_{IM_{3h}} \leqq -101dBm$ ≦and $P_{IM_{3\ell}} = -142dBm$. These low power levels are still further attenuated by the transmitter Tx output antenna filter and adaptative circuits and their interfering effects are negligible. A second worst case scenario occurs when two handsets are operating far from the base antenna but at a distance $d \leq 200\text{m}$ and a minimal distance of $d_r = 3\text{m}$ between the handsets' antennas as shown in Figure 6. In this case $P_T = 10\text{dBm}$ due to the large distance from the base station.
$P_{f1,2} = P_{f2} = 10mW, P_{f12} = 10 - 41 \simeq -31dBm$ and from equations 16 and 17, $P_{IM3h} \leq -71$dBm and $P_{IM3\ell} \leqq -112$ dBm at the transmitter output. The worst case co-channel interference to a neighboring receiver with a minimum A_{FS}=41 dB and $P_{Ril} \leq -153$dBm, which effect can also be neglected, will result in $P_{Rih} \leq -112$ dBm. The transmitter 2nd and higher order IM products can all be neglected due to the selectivity of the transmitter output circuits described in Figure 4 [14]. Therefore transmitter IM product interference will not affect the open site nanocell CT-2 system.

4. Single tone spurious effects

Single Tone Spurious (STS) effects are inherent in superheterodyne receivers because of the nonlinear behavior of the mixers and frequency converters, where output frequency mixing includes the difference and the sum of the RF input frequency f_0 with the LO frequency f_L and the N harmonic spurious products of f_0 beating with the $|M|$ harmonic products of f_L where:

$$f_{mixing} = |\pm Mf_L + Nf_0| \tag{18}$$

If the spurious power levels generated exceed the receiver sensitivity threshold-to-interference level, disturbances may occur. Disturbances can, therefore, occur from each external interfering signal or its harmonics which reach the receiver mixer and result in a beating product frequency that is not sufficiently attenuated by the selective IF filters [7].

Receiver front-end selective circuits, also contribute in attenuating part of the STS interfering signals, especially the disturbing image frequency to a reduced power level sufficiently below the receiver detection sensitivity threshold [21]. A prohibited list that includes all potentially disturbing input signal frequencies to avoid can be obtained from the receiver front end circuits parameters and the system operational scenarios [7], by using a special computer program [21].

In the absence of desired transmitter signals, mixing products from an interfering STS signal may cause tedious disturbances which will not degrade performances but may be annoying to system users only because it will not affect significantly the $S/_{N+I}$ when the desired received signal is present [7, 10].

5. Desensitization effects computation

The minimal realistic distance between the handset transmitter and the base receiver antennas is $d = 3m$. Thus from equation (4) the propagation dispersion loss is only , $A_{FS} = 41dB$ as shown previously. The handset transmitter power level is very low $P_T \leq 0dBm$, due to the Common Air Interface (CAI) dynamic adaptive power control [5].

From equation 10 when the specified system Rx threshold power level is $P_{Rs} = -89dBm$, the required A_s is around

$$A_s \geqq P_T + G_T - A_{FS} + G_R - P_{RS} \tag{19}$$

Therefore in the realistic worst case $A_s \geq 53dB$ and the most proximate adjacent channel which provide sufficient frequency attenuation A is from the Transmitter spectrum response of Figure 4, $(f_0 \pm 0.3)MHz$.

At this frequency interval , the low interfering power level P_{RS} at the victim Rx is not sufficient to desensitize the preamplifier (characterized by $P_{1dBG_c} \approx -35dBm$) and the following active stages [7]. Therefore the victim base receiver will operate in linear characteristics conditions. The interfering signal will not affect the receiver selective IF circuits due to an additional frequency attenuation A_f exceeding 40 dB. Thus, direct adjacent channel interference effects are negligible [12]. From the reciprocal principle which can be applied in case of linear systems [16;21] the second transmitter interference effects to the operating receiver are also negligible. A second worst case scenario occurs when two handsets are operating far from the base antenna but at a distance $d \leq 200m$ and a minimal distance of $d_r = 3m$ between the handsets' antennas as shown in Figure 6. In this case $P_T = 10dBm$ due to the large distance from the base station. From Table 1 results, the base station receiver power input level is

$P_r \approx -65\text{dBm}$. From equation (13) $A_s \geq 24\text{dB}$ and the base Rx dynamic channel selection process may choose in this case even the 1st adjacent channel at frequency $(f_0 \pm 0.1)MHz$. The worst case path is between the two handset antennas where the adjacent channel spurious interference power level P_{RS} at the second handset receiver can be computed from equations (16) and (17). Using the scenario parameters $P_T = 10dBm$, $A_{FS} = 41dB$, $A_s \approx 36dB$, $A_{\Delta f} \approx 2dB$ and $G_T = G_R \simeq 0dBi$ [7] we obtain $P_{RS} \simeq -68dBm$.

In this realistic worst case scenario the victim handset receiver will not be desensitized at all at these relatively low power levels and the receiver frequency attenuation to the 1st adjacent frequency signal is exceeding $30dB$. The result is an interfering power level P_{RS} less than –98 dBm which is significantly lower than the desired power level of $-65dBm$ shown in Table 1. Therefore even for these realistic worst case conditions the transmitter power level will not desensitize the receiver front end active stages. These interfering signals are strongly attenuated by the receiver IF selective filters and therefore will have no effect on the CT-2 outdoor system operation.

6. Additional intrasystem mutual interference sources

Effects of the additional co-channel mutual interference sources, shown in Figure 3, can be neglected due to the system transmitter harmonics and receiver local oscillator (LO) spurious signals frequencies that fall outside the band of 891 to 895 MHz. The receiver is always operated in its linear characteristics zone excited by input power level below the P_{1dBc} upper dynamic range limit. Thus, AM to PM distortion effects can be neglected due to sufficient linearity of the transmitter and receiver described previously [6;21].

The transmitter non-harmonic broadband noise power level P_{BN} is specified as less than -70dBc [5]. The worst case interfering distance of 3m produces a minimum dispersion loss of $A_{FS_{min}} = 41\text{dB}$ between the antennas. Therefore, even for the highest interfering transmitter output power level ($P_{T\max} = 10\text{dBm}$), the broadband noise power level P_{BN_r} at the victim receiver input will be around -101 dBm just below the -100dBm, threshold limit which will not affect the desired signal reception. Thus, the transmitter non-harmonic broadband P_{BN} effects and the other minor sources of intrasystem interference presented in Figure 3 can always be neglected. In the analyses of the system intrasystem interference effects two handset were considered . The assumption is based on the fact that the total number of available channels is only 40, without considering the frequency reuse effect from neighboring CT-2 nanocells, in order to avoid harmful cochannel interference between cells. The probability that more than 2 persons are using their headset simultaneously at an LOS distance of less than 3 m is very low. Furthermore, under LOS propagation condition between handsets, if a third or more simultaneous users are operating at a distance further than 10 m, the dispersion attenuation will be at least $20\log(10/3) \simeq 11dB$ higher without considering the filtering effect of the victim receiver on the remote interfering signal. Dynamic channel allocation via DSP techniques can add at least 36 dB more attenuation from the frequency differences of additional users.

IV. Conclusions

In this paper the intrasystem interference effects for an outdoor nanocell CT-2 system have been analyzed and computed and the equations presented can be included in a computer program for simulation of interference power levels compared to the desired signals in order to predict system performance.

The main conclusions are:

1. System CAI adaptive power control [5,10] enables operation at very low transmitter power levels of -10dBm to 0 dBm for horizontal distances of about 70 m from the base station antenna. This can increase to a maximum of 10dBm at a cell maximum operational distance of 200 m. This power control mechanism significantly decreases the risk and effects of non-linear intrasystem interference.
2. The PCS system receiver dynamic channel selection process [7,10] reduces harmful linear cochannel and adjacent channel interference effects, even in case of near collocation situations.
3. Realistic worst case receiver IM power levels [20] are very low and their effects can be neglected due to cosited low transmitter power levels and relatively high system receiver dynamic range. Even the most harmful receiver 3rd order IM power level of $P_{IM3_h} \leq -95dBm$, as computed in section III.2, can be neglected.
4. Realistic worst case transmitter 3rd order IM power levels of ($P_{IM_{3_h}} \leq -101dBm$) [12] are still lower than receiver IM. This is due to the linearity and high intercept point power level of the power amplifier stage. This IM product and all other IM products of lower power levels generated in the transmitter can also be neglected.
5. There is no risk of receiver desensitization [13,20], even for a realistic worst case distance separation of 3 m between two handsets as computed in section III.5.
6. The effects of all non-linear cochannel, adjacent channel and out of band intrasystem interference sources, presented in Figure 4, can be neglected except the Single Tone Spurious (STS) effects discussed in section III.4.
7. STS interference frequencies and realistic worst case power levels can be computed using semi-empirical methods [21]. The number of potentially disturbing frequencies in the list are very few for the CT-2 system, which is useful for frequency management purposes. A list of forbidden STS spurious spot frequency which are potentially harmfully to the system receiver can be provided. These interference effects can still be significantly reduced or even avoided by modifying receiver front end parameters using simple semi-empirical optimization and simulation methods, but this solution may be practical only for the next generation of PCS receivers [20].

The pico-cell PCS indoor interference effects analysis and computation are different than those of outdoor scenarios [22] and will be presented in a following paper. However, due to indoor obstructions and shadowing, the effect of intrasystem interference will be reduced. The effects of intersystem interference on nano-cell and pico-cell will also be presented in a following paper.

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APPENDIX

Table 2: Required CT-2 transmitter's and receiver's specified parameters

Tx parameters	***Typical values***
Frequency Band	f_{0}= (891-895) MHz
Channel spacing Bandwith	Δf=100 kHz Bn=84 kHz
Maximum Power level	P_T =10 mW
Power Control Variation	$-10 < P_T \leq 10dBm$
Encoding Technique	ADPCM (32kbit/s)
Frequency peak deviation	(14.4-25.2) kHz
Output frequency response (see figure 4)	$P_T \leq \begin{cases} -36dBm & \lvert\Delta f\rvert \geq 100kHz \\ -70dBm & \lvert\Delta f\rvert \geq 500kHz \end{cases}$
Power Amplifier Linearity Power Amplifier Intercept. Point	Class A linear amplifier. P_{IP3} =30 dBm
Receiver parameters	***Typical values***
Sensitivity	$P_{sen_m} \geq -109dBm$ $P_{sen} = -94dBm$ for BER of 10^{-3}
Noise Figure	F_R = 9 dB; for worst case 10 dB
Front End Third Order Intercept Point	$P_{IP3} = -22dBm$
Desensitization power level	$P_{des} \leq -35dBm$
Antenna characteristics & dimensions	Headset whip $1.2 \leq h_{handset} \leq 1.8m$ Base station: Vertical monopole $3 \leq h_{base} \leq 7m$

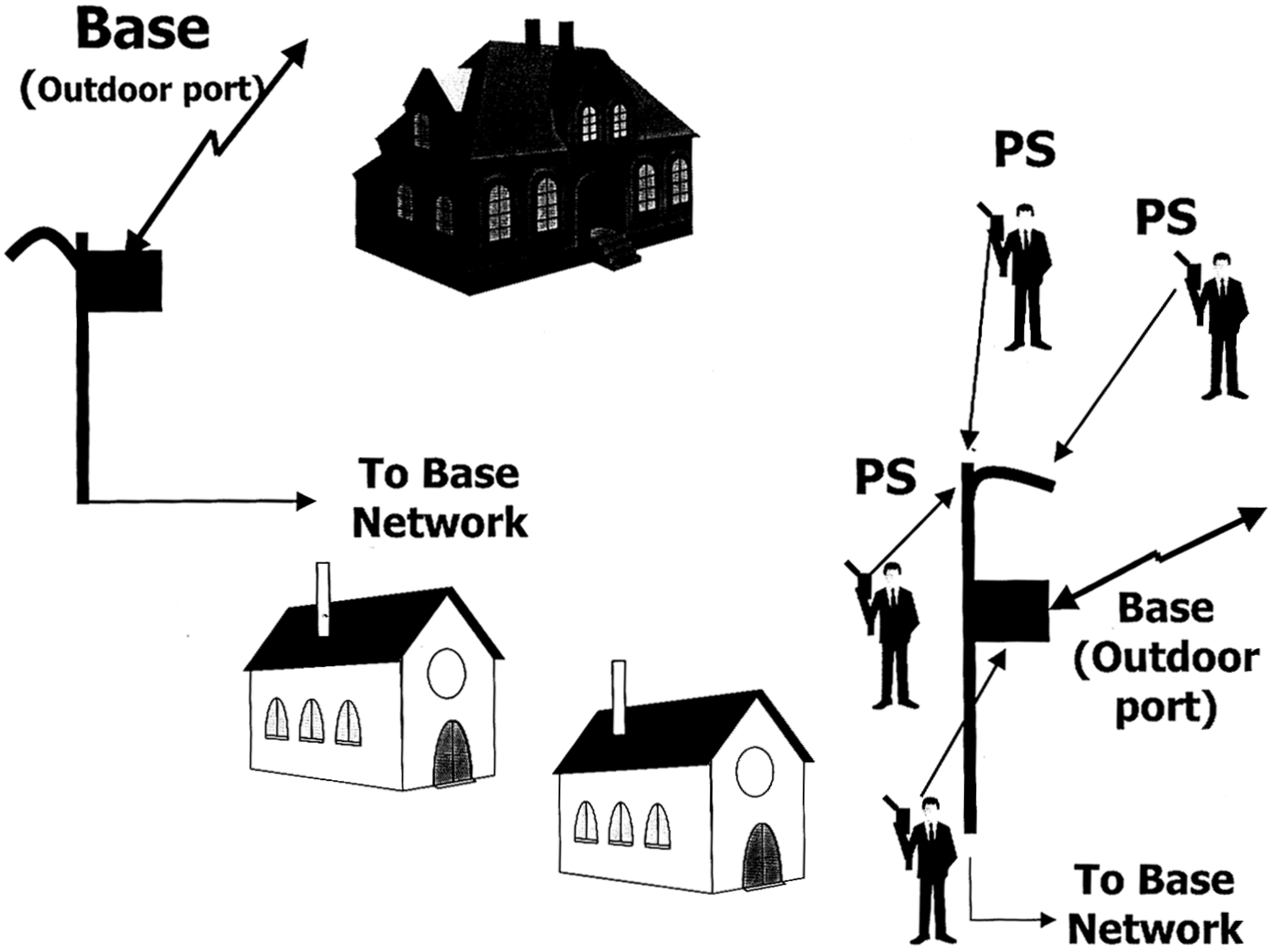

Figure 1 : Open site outdoor personal communication operation scenario

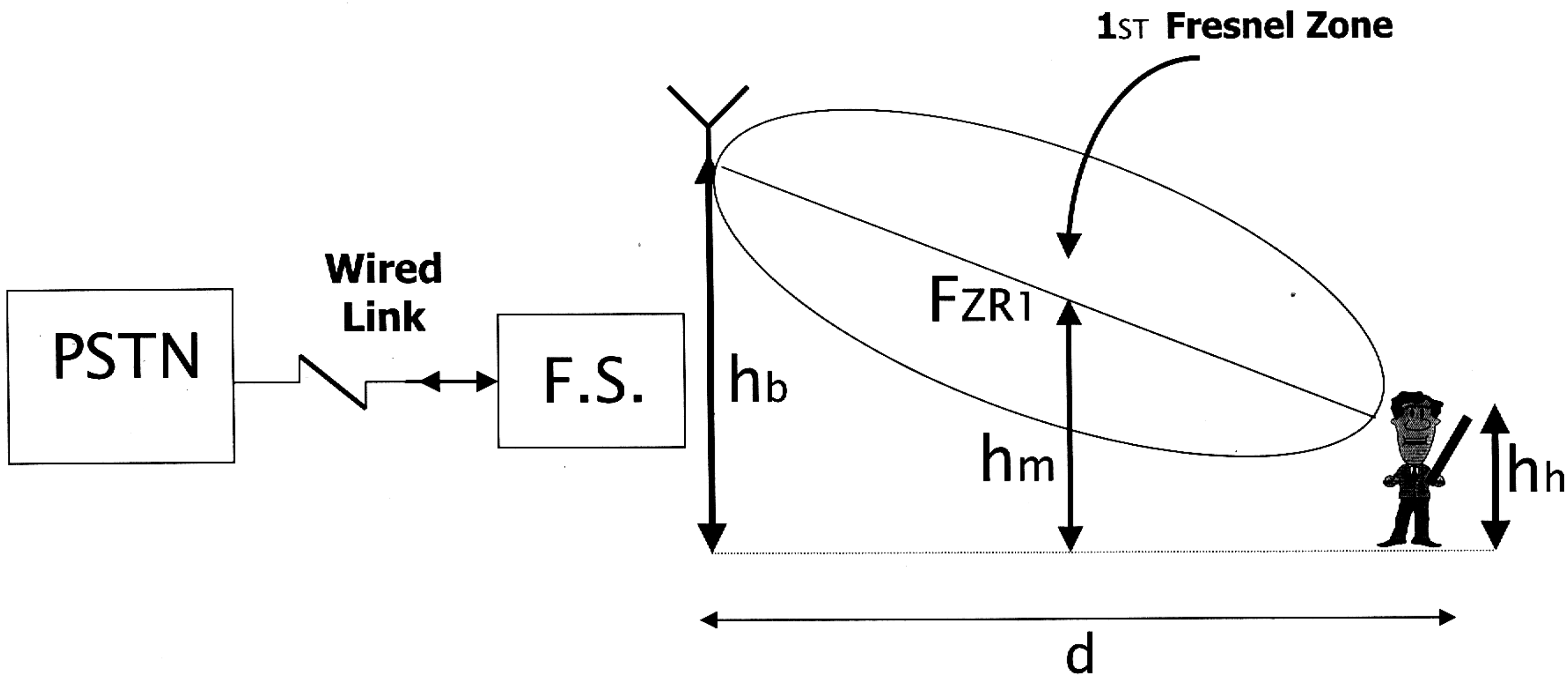

Figure 2 : Outdoor (open site) personal communication LOS operation conditions using first Fresnel Zone ellopsoid criteria

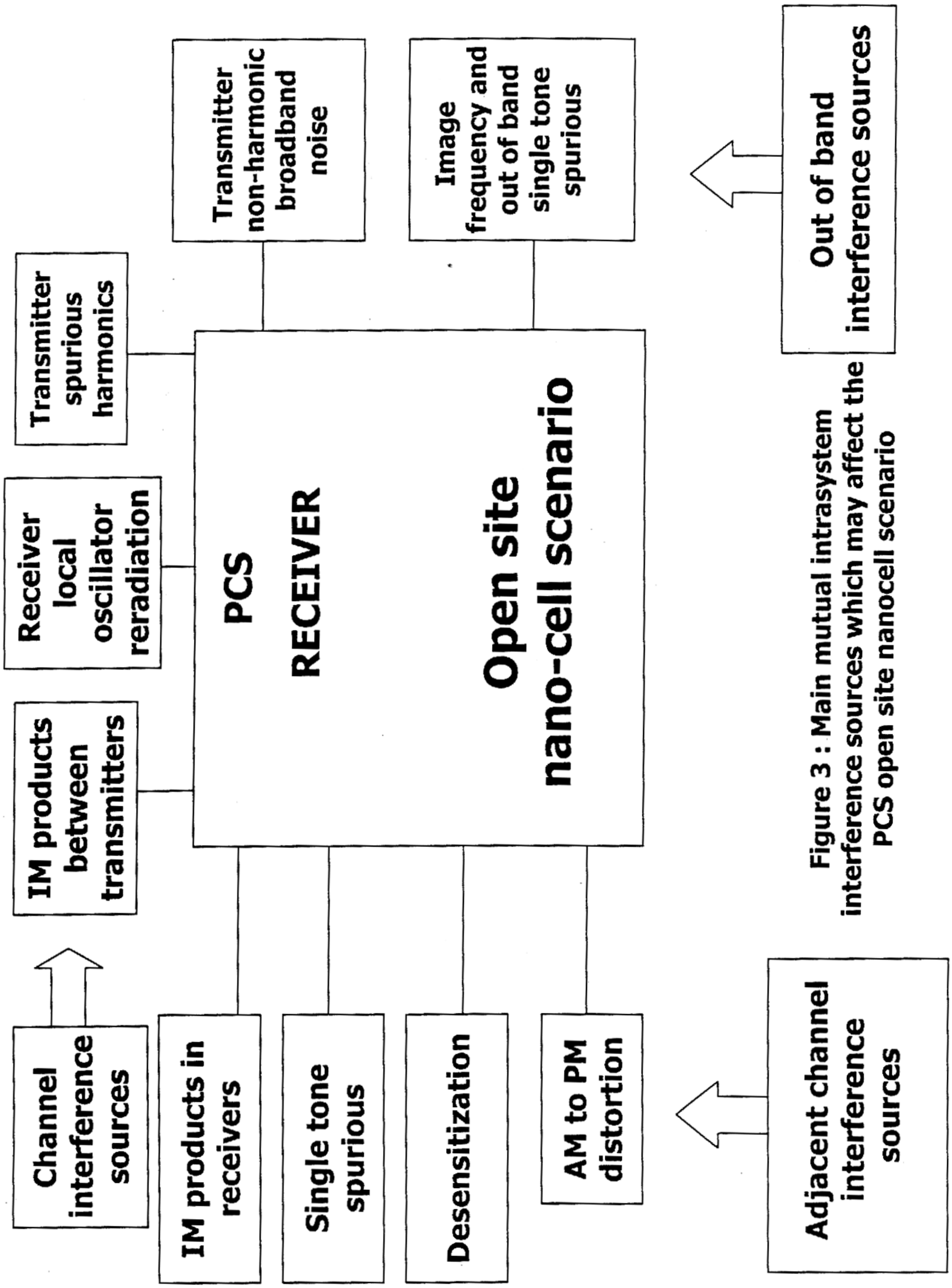

Figure 3 : Main mutual intrasystem interference sources which may affect the PCS open site nanocell scenario

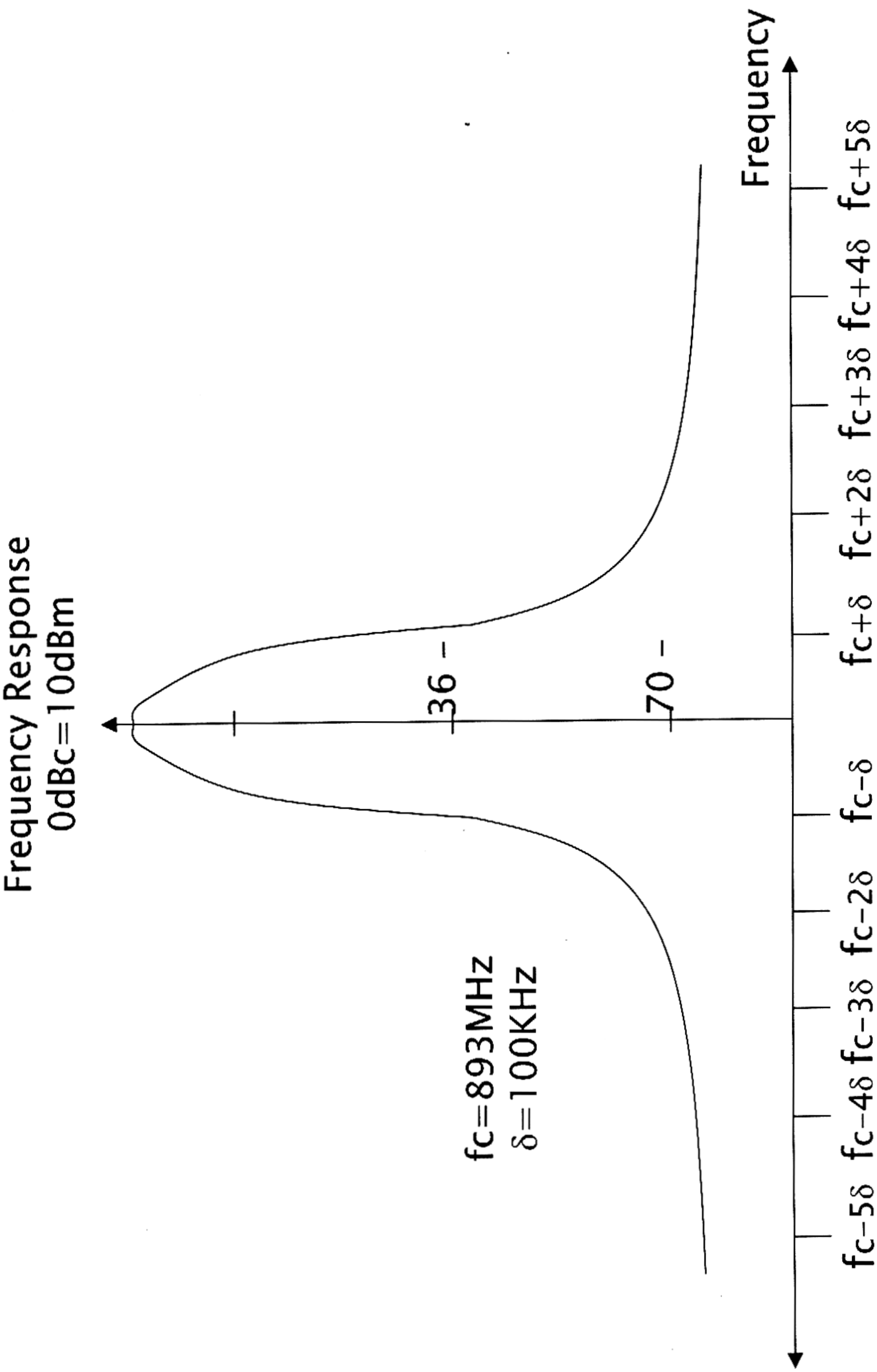

Figure 4 : PCS-CT-2 Spectrum of the transmitted signal

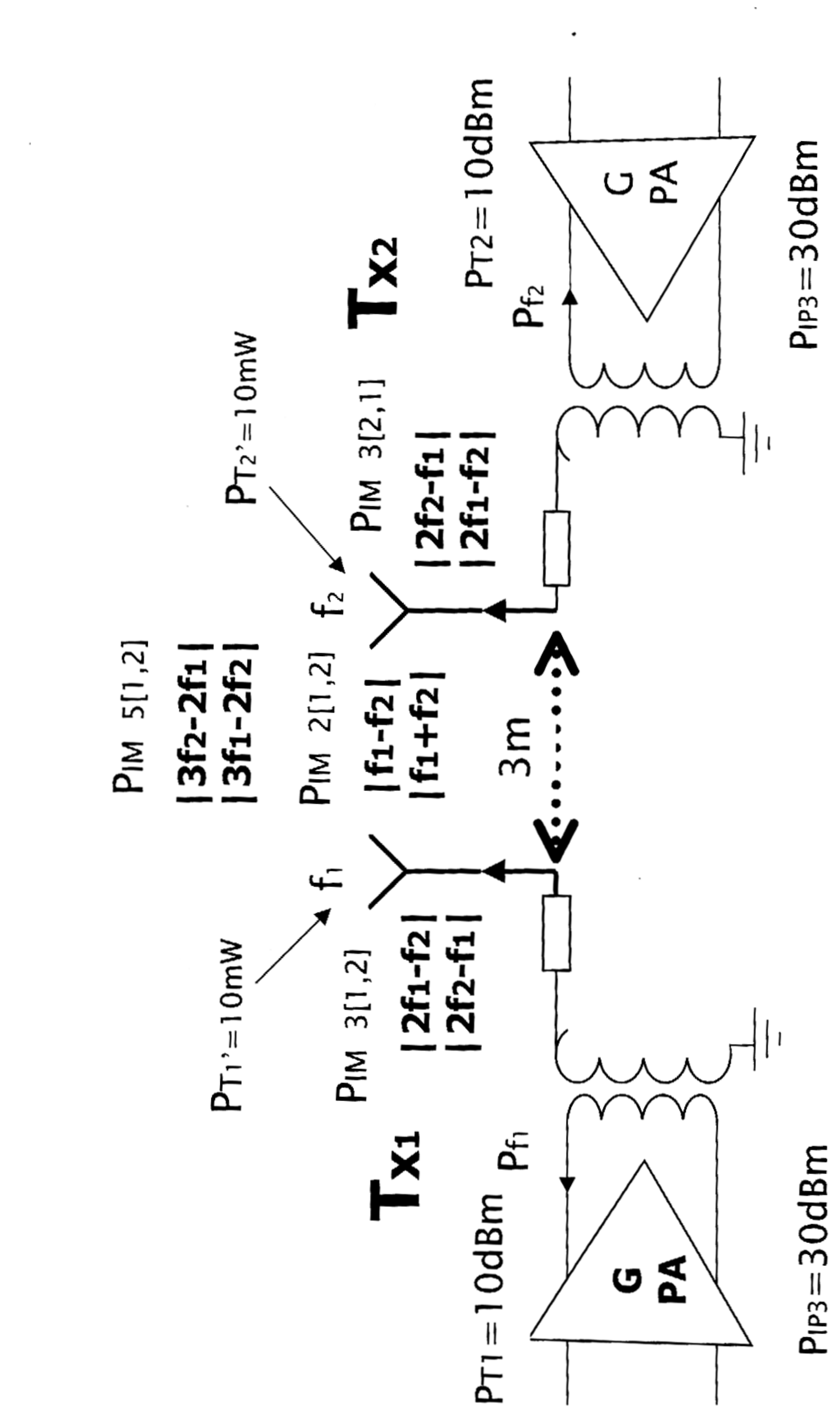

Figure 5 : Schematic of final stage of PCS transmitter presenting the intermodulation product power level computational method

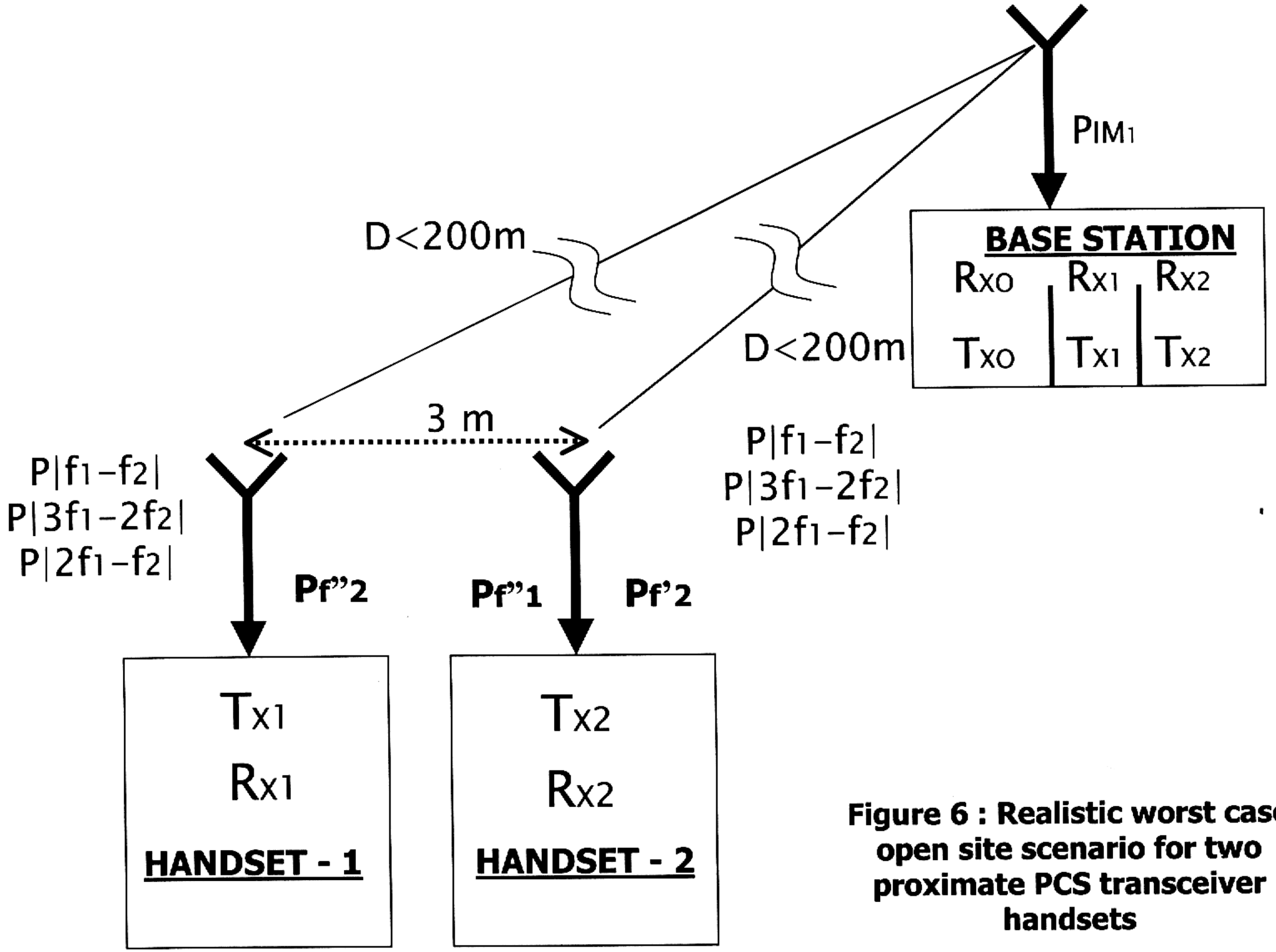

Figure 6 : Realistic worst case open site scenario for two proximate PCS transceiver handsets