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Deployment considerations for TDD Fixed Wireless Access (FWA) systems;
Autonomous Frequency Assignment (AFA);
Part 1: Proof of concept simulation

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Transmission and Multiplexing (TM).

The present document is part 1 of a multi-part deliverable covering deployment considerations for TDD Fixed Wireless Access (FWA) systems; Autonomous Frequency Assignment (AFA), as identified below:

Part 1: "Proof of concept simulation";

Part 2: "AFA equipment procedure implementation".

Introduction

Great effort has been expended to quantify the FWA co-existence issues for regulators, operators and standards groups. Coexistence for FWA systems includes technology coexistence (TDD/FDD) as well as coexistence between multiple operators. The multiple operators issue involves two scenarios: (1) same area, adjacent channel, and (2) adjacent area, same channel. Work on coexistence has principally involved ETSI TM4 [1] and [2] and the working group SE19 of the CEPT/ERC [3] and [4] in Europe, and the IEEE 802.16 TG2 [7] in North America.

While all methods studied are required to assume certain "idealized" global system assumptions, it is informative to note that each has reached comparable coexistence conclusions. This is particularly important for the same area/adjacent channel case where it has been clearly identified that a guard band is required and/or that inter-operator co-ordination is essential.

The present document studies the use of autonomous or automatic frequency assignment for hub sectors as an equipment means to reduce or avoid the need for *a-priori* guard bands as recommended by the standards and regulatory groups.

1 Scope

The present document studies the use of Autonomous Frequency Assignment (AFA) (also called automatic frequency assignment) for hub sectors as an equipment means to reduce or avoid the need for a-priori guard bands as recommended by the standards and regulatory groups. The present document gives guidlines for radio frequency deployment considerations and is applicable mainly for TDD Fixed Wireless Access systems.

2 References

For the purposes of this Technical Report (TR) the following references apply:

[1] ETSI TR 101 904: "Transmission and Multiplexing (TM); Time Division Duplex (TDD) in Point-to-Multipoint (P-MP) Fixed Wireless Access (FWA) systems; Characteristics and network applications".

[2] ETSI TR 101 853: "Fixed Radio Systems; Point-to-point and point-to-multipoint equipment; Rules for the co-existence of point-to-point and point-to-multipoint systems using different access methods in the same frequency band".

[3] CEPT/ERC Report 97: "Fixed Wireless Access (FWA) spectrum engineering & frequency management guidelines (qualitative)".

[4] CEPT/ERC Report 99: "The analysis of the coexistence of two FWA cells in the 24.5 - 26.5 GHz and 27.5 - 29.5 GHz bands".

[5] CEPT/ERC/REC 00-05: "Use of the band 24.5 - 26.5 GHz for fixed wireless access".

[6] Matthew M-L Cheng and Justin C-I Chuang: "Distributed Measurement-Based Quasi-Fixed Frequency Assignment for TDMA Personal Communications Systems" ICC 95 Seattle.

[7] IEEE 802.16.2-2001: "IEEE Recommended Practice for Local and metropolitan area networks Coexistence of Fixed Broadband Wireless Access Systems".

[8] ITU-R Recommendation P.1410-1: "Propagation data and prediction methods required for the design of terrestrial broadband millimetric radio access systems operating in a frequency range of about 20-50 GHz".

[9] CEPT T/R 13-02: "Preferred channel arrangements for fixed services in the range 22.0-29.5 GHz".

[10] ETSI EN 301 213: "Fixed Radio Systems; Point-to-multipoint equipment; Point-to-multipoint digital radio systems in frequency bands in the range 24,25 GHz to 29,5 GHz using different access methods; Part 3: Time Division Multiple Access (TDMA) methods".

[11] ETSI TR 102 074: "Fixed Radio Systems; Mixed mode operation in MultiPoint (MP) Time Division Multiple Access (TDMA) Fixed Wireless Access (FWA) systems; Intersystems co-existence".

3 Symbols and abbreviations

3.1 Symbols

For the purposes of the present document, the following symbols apply:

dB	decibel
dBm	decibel relative to 1mW
GHz	GigaHertz
kbit/s	kilobit per second

Mbit/s	Megabit per second
MHz	MegaHertz

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

AFA	Autonomous Frequency Assignment
ATPC	Automatic Transmit Power Control
CEPT	Conférence Européenne des Postes et Télécommunications
CS	Central Station
C/I	Carrier to Interference ratio
LIA	Least Interference Algorithm
LoS	Line of Sight
P-MP	Point to Multipoint
PACS	Personal Access Communications System
PHS	Personal Handyphone System
QAM	Quadrature Amplitude Modulation
QSAFA	Quasi Static Autonomous Frequency Assignment
RS	Repeater Station
TDD	Time Division Duplex
TDMA	Time Division Multiple Access
TS	Terminal Station
RS	Repeater Station
Tx	Transmitter
Rx	Receiver

4 General context and background

FWA systems can operate with TDD or FDD channel arrangements. Channel plans, such as CEPT T/R 13-02 [9] can easily be deployed, in either case.

In addition to the terminal-to-hub interference associated with FDD, TDD systems have terminal-to-terminal and hub-to-hub interference couplings. The narrow beam widths of the terminal station antenna, in conjunction with in-bound power control, help to suppress terminal-to-terminal couplings. Use of wide angle sector antennas at the hub results in the hub-to-hub coupling to be the more challenging of the two.

Document CEPT/ERC/REC 00-05 [5] recommends the use of guard bands or guard distances [at 26 GHz] to minimize interference between operators on adjacent channels in the same area, or the same channel in adjacent areas. TDD systems require additional guard bands and/or distances as a consequence of the additional interference mechanisms. Operators can circumvent the guard band requirement by co-ordinating their deployments. While certainly preferable over mandated guard bands, co-ordination may be difficult in practice. As competitors, operators have historically considered cell plans and site locations extremely confidential. Regulators also do not necessarily wish to enforce co-ordination upon operators.

5 Autonomous Frequency Assignment (AFA)

TDD's inherent ability to send and receive on the same frequency can be leveraged to provide an alternative to co-ordination and pre-assigned guard bands through autonomous frequency planning (AFA) schemes. Such techniques have been used successfully in DECT, PHS, and PACS systems. In these systems, base stations constantly monitor the spectrum and effectively create an air traffic "map" of the operating band. Every time a handset attempts a call, a frequency assignment is made that minimizes in-channel and adjacent channel interference. For FWA systems, only the hubs are required to map the band of interest. They then select an operating frequency that minimizes co-channel and adjacent channel interference. Re-assignment is anticipated to be an infrequent event consistent with the rate at which new hubs are added to the area.

5.1 Algorithm

One AFA algorithm under consideration is quasi-static autonomous frequency assignment (see clause 9.1 and [6]). QSAFA is a measurement-based (rather than prediction-based) approach to the frequency assignment problem and is used in PACS. Using hub-to-hub interference as a simple example, when a new hub sector is introduced, it would initially leave its transmitter turned off and perform a frequency scan across the total allowed spectrum of carriers, measuring and recording the received interference power vs. carrier frequency. The carrier frequency, within the operator's allocation, corresponding to the minimum received power would be chosen as the frequency for this new sector. This effectively results in at least one guard channel separation between neighbouring hubs. Note that knowledge of the duplex spacing used by the FDD operator must be known *a priori* as the TDD sector employing AFA can only detect the location of the FDD *transmit* frequency. However, this should not be an issue for CEPT bands for which the FDD duplex spacing is clearly and rigidly specified.

5.2 Usability and features

Autonomous Frequency Allocation (AFA) may provide an alternative to frequency coordination and pre-assigned guard bands in troublesome interference environments, and has potential advantages over the sole use of an *a priori* worst-case predictive plan. AFA responds to the actual interference within a real system at some point in time, rather than predictions based on worst-case line-of-sight (LoS) conditions and future (yet-to-be-built) extensive cell layouts based on regular grids. In actuality, cell layouts may be irregular, both in cell size and in cell location, in the real world environment of building blockages and non-uniform geographic distribution of customer terminals and traffic densities. The ability of AFA to respond to actual rather than predicted interference results in a flexible, self-coordinating approach that can reduce reliance on unnecessarily prohibitive co-existence measures (based on prediction and worst-case alignment scenarios) such as pre-assigned guard bands, which may waste otherwise usable spectrum. In effect, AFA can create its own "localized" guard bands from the TDD channel spectrum by avoiding certain channels only when and where needed. In addition, the measurements performed in AFA are superior to predictions. For example, a channel frequency assignment that might be disallowed by an *a priori* plan could actually be permitted by an AFA scheme because of a building blockage circumstance. By the same token, based on measured intra- or inter-system interference, an AFA scheme might disallow a channel frequency assignment that was presumed to be suitable by an *a priori* re-use plan, either because the interference could not have been predicted or was poorly estimated.

The following features have been implemented in the simulations:

- Initial TDD frequency re-use plan to address potential intrasystem interference.
- 5 × 5 cell layout TDD system (covering a 36 km × 36 km area).
- Addition of TDD TSs.
- Overlay of multiple FDD cells (also a 5 × 5 cell).
- Ability to model building blockage between TDD CSs and TDD TSs.

Detailed descriptions of these features and the simulation implementation are provided in the present document, followed by simulation results.

Link budgets for 26 GHz, 3,6 km radius R, rain region K, and a list of assumptions are provided in annex A. Both the TDD and the FDD systems are assumed to use the same system parameters.

6 TDD system

6.1 Initial frequency re-use plan

An initial frequency re-use plan that addresses all significant TDD intrasystem interference mechanisms CS-to-CS, TS-to-CS, and CS-to-TS are shown in figure C.1. It is based on eight TDD carriers and a fundamental N=16 cluster size (cluster pattern repeats). This plan, combined with the other simulation elements described below, determines the starting interference environment for the QSAFA algorithm.

6.2 Addition of TSs

In each TDD sector, 32 randomly placed TSs have been added to the simulation, as shown in figure C.2. This type of placement is more realistic than assuming every sector has multiple TSs with worst-case alignments toward other CSs. After the initial placement of the 3 200 TSs, a winnowing process is performed. Only those TSs with potentially significant TDD TS-CS interference couplings are retained in the simulation for further processing. See figure C.3 for the 1 080 remaining TSs after the winnowing process (as compared to figure C.2). For the purpose of winnowing, all TS-CS paths are assumed to be LoS, and each TS is examined for all possible TS-CS interference couplings. If a TS can produce interference power of at least -100 dBm, on any channel frequency, into at least one TDD CS (resulting in a potential C/I $\leq$ 30 dB at that CS if it were to use the same channel), then the TS is retained in the simulation as a "significant" TS. The calculation of the interference coupling takes into account: antenna angular discrimination values at both antennas (including any cross-polarization discrimination), clear sky path loss, and proportional ATPC for the TS transmit power, based on the TS distance from its assigned CS (see annex A). Frequency discrimination is not included in the winnowing process because sector frequencies can change during the QSAFA iterations. Polarization assignments are not affected by QSAFA, and remain constant during its application. Antenna RPEs are detailed in annex A.

6.3 Building blockage

The (optional) ability to model building blockage between TDD CSs and TSs has been added to the simulation. This feature accounts for the fact that most TS antennas will be at a lower height than the CS antennas, and therefore building blockage is expected to occur on some paths between a TDD CS and a disassociated TDD TS (a TS assigned to another CS sector). The building blockage feature can be disabled so that all TDD TS-CS paths are LoS. Because there are 1 080 significant TDD TSs left in the simulation after winnowing, and each TS has a potential interference path with 99 other TDD CSs, this results in a the maximum number of TDD TS-CS LoS interference paths being 106 920. However, in the simulation results presented here, the building blockage model is always enabled, reducing the number of LoS interference paths between TSs and CSs to 4 790. Please note that even when the building blockage model is enabled for TDD TS-CS paths, the simulation still pessimistically assumes that all CSs (both TDD and FDD) are LoS to all other CSs, regardless of distance. This assumption may be altered to be more realistic in future simulations.

The building blockage model is based on the "Rayleigh Rooftop" model and the Malvern area building characteristics, as described in a report from Cellular Radio Access for Broadband Services (CRABS). Malvern represents a conservative data set in the sense that it is suburban in nature and has few tall buildings. An example of a LoS probability calculation over a path is provided in annex B.

For simulations to incorporate this building blockage model, height assumptions must be made for two types of radio elements (referred to as "TX" and "RX", and for the rooftop heights in the surrounding area. In the Malvern area, the rooftop heights roughly follow a Rayleigh distribution, with the most frequently occurring height being 7,6 m. In the simulations, all TDD CS antennas are assumed to be at a uniform 30 m height above the ground (maximum height used for "TX"), and all TDD TS antennas are assumed to be at a uniform 10,5 m height (height range used is 6,5 m to 11,5 m for "RX"). These height assumptions (both being at or near the maximums assumed) tend to be conservative in that they result in higher probabilities of visibility (smaller probabilities of blockage) along a path than shorter heights would.

See figure C.4 for LoS probabilities for various combinations of TX/RX radio heights vs. path distance between radios. Please note that the data plotted in figure C.4 correspond to the probability of LoS vs. distance along the path between a TX and RX. This is not the same data as plotted in the "coverage" graphs in the CRABS report (see Bibliography), which represent the two-dimensional "percent coverage" of circular areas (or percent of buildings covered), centred on a central TX, vs. circular radius.

To verify that this model was working as expected, several values of range D were selected, each with a small "bin" tolerance. The numbers of "blocked" TS-CS paths and "LoS" TS-CS paths in the simulation, with path lengths falling within the range bin, were counted. The ratio of LoS paths to total paths (LoS plus blocked) agreed reasonably well with the percentage of LoS paths expected for this range D. For example, there was a total of 2 048 TS-CS paths that were 7,8 km to 8,2 km in length. After applying the building blockage model, only 246 of these were LoS paths, giving a LoS percentage of 12 %, which agrees reasonably well with figure C.4's value of ≈11 % at 8 km, using the curve for RX = 10,5 m.

As a bookkeeping note, the ITU [8] blockage model differs from the original CRABS version, but the CRABS version was used in the simulations reported here. The AFA analysis with the ITU model could be the subject of a future report. In any case, the results presented here should be conservative, because the ITU version estimates an average of 9 buildings/km along a ray path, while the CRABS version estimates only 3. Since each additional building in a path presents an extra probability factor for blockage, the CRABS version generally predicts a larger LoS probability for a given path length.

7 Introduction of multiple FDD cells

The (optional) ability to overlay multiple FDD cells among the TDD cells has been added to the simulation. The FDD operator's basic system parameters, such as channel bandwidth, transmit (TX) power, receive system (RX) noise floor, antenna patterns, etc., are assumed to be the same as that of the TDD system (see annex A). A significant difference between the two systems is the aggressive FDD frequency re-use plan shown in figure C.5 (only outbound channel colours are shown). This re-use plan employs only two outbound channels (FDD CSs transmit on FDD channels 3 or 4) and two inbound channels (FDD CSs receive on FDD channels 7 or 8). When no guard bands are employed between the TDD and FDD spectral blocks, (see figure C.6(a) the outbound FDD channels 3 and 4 are 2nd and 1st adjacent channels, respectively, to TDD channel 1, while the inbound FDD channels 7 and 8 are 2nd and 1st adjacent channels, respectively, to TDD channel 5. The frequently repeated occurrences of the limited number of outbound and inbound FDD channels result in several adjacent/near-adjacent channel exposures between the two operators when no guard bands are employed. By contrast, a less aggressive FDD re-use plan would draw on a larger number of channel frequencies, spreading out the interference power over FDD channels that are farther removed in frequency from the TDD channels.

The relative spacing of the TDD and FDD channel plans is shown in figure C.6, illustrating two assumptions: (a) adjacent spectral blocks with no guard band between each set of operator's bands, and (b) with one guard band (equal to a channel bandwidth) between each set of operator's bands. Each operator has 8 channels (TDD channels 1 to 8 and FDD channels 1 to 8), and a "normalized frequency" (number inside the coloured boxes) corresponds to each channel, as shown. The magnitude of the difference between two normalized frequencies is used to determine the correct net filter discrimination value to apply when interference is not co-channel. For example, in figure C.6(a), frequencies 100 and 101 are 1st adjacent channels, with an assumed net filter discrimination (NFD) of 27 dB. Note that in figures C.5 and C.6, the FDD "greyed out" channel boxes represent unused channels in this particular FDD re-use scheme.

The two TDD/FDD intersystem interference mechanisms addressed in the simulations are:

- FDD-CS-to-TDD-CS interference.
- TDD-CS-to-FDD-CS interference.

NOTE: See next the clauses 8 and 9 on simulated interference mechanisms and QSAFA for the detailed list of all the interferences "taken into account" in the simulations, both for inter and intra systems.

Referring again to figure C.6(a) for the case of no guard bands as an example, the first mechanism is caused primarily by the FDD outbound "light cyan" channel #4 (normalized frequency 0) interfering into the adjacent TDD "red" channel #1 (normalized frequency 1). The second situation is caused primarily by the TDD "black" channel #5 (normalized frequency 101) interfering into the adjacent FDD inbound "dark cyan" channel #8 (normalized frequency 100).

The first mechanism results in measurable outbound interference from an FDD CS into a TDD CS, and this measurement can be used directly by the QSAFA algorithm to mitigate FDD-to-TDD interference. The second mechanism does *not* result in measurable interference at a TDD CS, since this involves the FDD CS inbound channel. In order to avoid producing TDD CS interference into FDD CSs, the QSAFA algorithm must have *a priori* knowledge of the FDD channel plan, and can then use reciprocity to infer TDD- to-FDD interference on the FDD CS inbound channel frequency, based on the FDD- to-TDD interference measured (at a TDD CS) on the FDD outbound channel frequency. This is addressed in more detail in later clauses. Note that interference mechanisms between one operator's CS and the other operator's TSs are not included in these simulations since the main purpose here is to evaluate how well QSAFA can respond to an extremely stressful interoperator CS-to-CS interference environment (see annex C for simulation details).

As shown in figure C.7, the entire grid of FDD operator cells (small four-sector icons for purposes of the overlay) has been overlaid on the TDD grid, where the TDD frequency plan shown is the initial plan from figure C.1. For viewing clarity, the TDD TSs are not shown from this point on, but are present in the simulation. The particular example shown in figure C.7 actually has a 100-meter offset between the two grids, but it is not perceptible due to the scales involved.

The FDD polarization is represented as a superimposed dot on the FDD sector icons as follows: black dot = horizontal, white dot = vertical.

Simulations were performed using a fixed 100-meter offset distance between the two operator grids, with four different bearings - NE, SE, NW and SW. Additional simulations were performed with random offsets on a cell-by-cell basis. The purpose of these simulations is to determine how well the QSAFA algorithm can address such an unrealistically stressful CS-CS interoperator interference environment while simultaneously handling TDD intrasystem interference. It should be understood that all statements made with regard to simulation results in the present document are based on these particular FDD overlay-offsets; results may vary for others.

8 Simulated interference mechanisms

To summarize, the following interference mechanisms are simulated and addressed (directly or indirectly) by the QSAFA algorithm when all radios in a TDD sector "go silent" to measure the interference environment:

- TDD Intrasystem:
    - CS-to-CS;
    - TS-to-CS;
    - CS-to-TS.
- TDD/FDD Intersystem:
    - FDD-CS-to-TDD-CS;
    - TDD-CS-to-FDD-CS (indirect).

These are described in more detail in the clause 9.

9 Quasi Static Autonomous Frequency Assignment (QSAFA)

9.1 High level description

The QSAFA algorithm converges to a local minimum of interference by having each TDD sector, in turn, go silent (turn off) and measure interference vs. frequency across the spectrum of available TDD channels (plus some adjacent spectrum to directly measure interference from other operators - e.g. FDD in this instance). After a TDD sector finishes measuring the spectrum of interference (with some additional required post-processing), the QSAFA algorithm selects a channel for this TDD sector that has the minimum interference power. Then the radios in that TDD sector return to normal operation using the newly-selected channel assignment, and the process moves on to the next sector.

This particular version of the algorithm is called QSAFA-LIA, where LIA stands for "Least Interference Algorithm". The algorithm accomplishes two objectives that lead to convergence: interference into this sector is reduced and interference from this sector into other sectors is reduced. In a single iteration, each sector in the TDD system takes its turn at going silent and measuring. When the N^{th} iteration through all the sectors produces no channel re-assignments, the algorithm has converged and the final C/I at each radio element is determined. The interference environment is improved after convergence, although no minimum C/I can be guaranteed. A slight modification (described later) to the channel selection process may be imposed to deal with the presence of an FDD operator.

Note that QSAFA is applied only to the TDD system and therefore affects only the TDD channel assignments in response to interference. Also, as previously stated, QSAFA does not affect polarization assignments.

9.2 Simulation implementation details

This clause describes implementation details of the simulation of the QSAFA algorithm and its application to the total interference environment produced by TDD CSs, TDD TSs, and FDD CSs.

9.2.1 Sequencing through TDD sectors

The simulation sequence followed in turning sectors off to measure interference is simply the order of the sector numbers shown in figure C.1. This area can be explored in the future to see if any other order has any advantage. Some other sequences have been briefly explored, but no significant advantage has been discovered through this cursory examination. At a minimum, it is probably best to sequence through all four sectors within a TDD CS cell before going on to another cell, since these four CS antennas share a rooftop and therefore their channel choices will have a relatively strong mutual effect.

9.2.2 Representing interference in the simulation

All examples in the remainder of this clause use a hypothetical TDD Sector A that has gone silent in order to measure interference vs. frequency, so that QSAFA can choose the minimum-interference channel for sector A to use before it turns back on. The examples given for sector A apply, of course, to all of the succeeding sectors (B, C, etc.) in an iteration, but the concepts can be easily illustrated from the perspective of just a single sector. Keep in mind that all CS-CS paths are always considered to be LoS, while each TDD TS-CS interference path may or may not be LoS depending on the random outcome of the building blockage modelling for that path. In addition, when a sector goes silent, it should be emphasized that this sector is no longer associated with its previously assigned channel frequency. It is now simply an unbiased observer/recorder of interference vs. frequency in the surrounding environment.

In summary, when sector A goes silent, measurements of interference vs. frequency are "performed" by the simulation as mainly follows:

- **Sector A CS intrasystem measurement:** Examines interference along all TDD paths between the Sector A CS radio and all of the CS and visible TS radios in the other 99 TDD sectors. Since in a TDD system, only one radio in a sector is transmitting at any given time, only a single "worst" radio (CS or TS) in each of the 99 other sectors is chosen to represent the maximum possible interference from that sector.
- **Sector A CS intersystem measurement:** Examines outbound interference from each of the 100 FDD CSs (outside of but adjacent to the TDD spectrum). Interference from TDD into FDD inbound channels is inferred from these measurements, using reciprocity, in a post-processing step.
- **Additional processing needed for QSAFA:** Some additional processing is performed in order to combine the multiple measurement sets into one reference set for QSAFA to use in the channel selection for Sector A.

NOTE: More detailed explanations and assumptions relating to the above steps may be addressed.

9.2.3 Real-World application to a TDD system

All of the measurement and post-processing steps described above could be performed in a real TDD system in the following manner. The QSAFA functionality could be apportioned into two pieces:

a) Localized tasks performed at each sector CS: All of the computational steps for:

   i) Consolidation of the measurements into a single reference set for that sector.

   ii) Addressing FDD interference (assuming knowledge of FDD paired channel plan).

   iii) Choosing the minimum-interference channel for that sector.

b) Centralized tasks performed at the central network management entity for all TDD sectors:

   i) The sector sequencing (including the order and the timing), including telling each sector when to take its turn going silent, and then receiving an indication back from that sector when it is through measuring/processing and ready to turn back on with the chosen channel assignment.

ii) Recognition when a complete iteration through all of the TDD sectors results in no further channel re-assignments (convergence), and notifying all sectors that the QSAFA process is complete.

10 Simulation results for 100-meter TDD-FDD grid fixed offsets

10.1 General comments

Simulations were run with and without QSAFA application ("before" and "after"), and with and without a single guard band, for four different diagonal 100-meter offsets between the FDD and TDD cell grids. In other words, the entire FDD grid is shifted relative to the TDD grid. All simulations start with the "Before QSAFA" TDD frequency plan as shown in figure C.7, which also shows the FDD overlay.

The FDD cell grid is offset relative to the TDD cell grid by 100 meters in one of four diagonal directions. These are very stressful, if unrealistic, scenarios designed specifically to tax the ability of the QSAFA algorithm to solve TDD-FDD CS-CS interference problems, while simultaneously addressing TDD intrasystem interference. As mentioned before, a 100-meter offset is not large enough to be detectable in figure C.7, but it should be easy to visualize the four offset diagonals, defined as follows:

- "NE" direction: (x-shift, y-shift) = (+70,7 m, +70,7 m).
- "SE" direction: (x-shift, y-shift) = (+70,7 m, -70,7 m).
- "NW" direction: (x-shift, y-shift) = (-70,7 m, +70,7 m).
- "SW" direction: (x-shift, y-shift) = (-70,7 m, -70,7 m).

The four directions are used to sample different degrees of coupling (dependent on polarization and FDD frequency) between the FDD and TDD sectors. For example, the "NE" shift results in the TDD sector 1 CS and the FDD sector 3 CS being 100 m apart and pointing directly (boresight) at each other. For purposes of the present document, this situation will be defined as a "proximate pair". This "NE" pattern continues with TDD sector 5 CS and FDD sector 7 CS forming another proximate pair, and so on, for a total set of 25 proximate pairs (note that some of these CS pairs use the same polarization, and some do not). By contrast, the "NW" shift results in the TDD sector 2 CS and the FDD sector 4 CS forming a proximate pair. This "NW" pattern continues with TDD sector 6 CS and FDD sector 8 CS, and so on, for a different set of 25 proximate pairs. The four diagonal directions produce four different sets of proximate pairs (25 in each set).

Of course, all of the FDD CSs and TDD CSs are considered to be LoS to each other, but the 25 proximate pairs will contain some of the worst interference cases, specifically where polarizations happen to match and the FDD channels happen to be nearest to the TDD spectrum (i.e. FDD channel pair 4 and 8). To gain some perspective on the potential magnitude of the TDD-FDD intersystem interference situation, a calculation is performed for a proximate pair that happens to be using the same polarization. The calculation uses the annex A assumptions, and results in the following baseline interference power before NFD is applied.

$$24 \text{ dBm} + 19 \text{ dBi} – 100{,}7 \text{ dB (FSPL)} + 19 \text{ dBi} = -38{,}7 \text{ dBm}.$$

Using the NFD values from annex A, this interference power would be reduced as follows depending on the spectral proximity of the frequencies involved (see note 1):

- 1^{st} adjacent carrier interference (NFD = 27 dB): -65,7 dBm.
- 2^{nd} adjacent carrier interference (NFD = 49 dB): -87,7 dBm.
- 3^{rd} adjacent carrier interference (NFD = 51 dB): -89,7 dBm.
- 4^{th}, 5^{th}, 6^{th}, (etc.) adjacent carrier interference (NFD = 55 dB): -93,7 dBm.

Assuming that C/I must exceed the required C/N threshold by 6 dB to introduce no more than 1 dB threshold degradation, the required C/I value for 4-QAM is 19 dB. For reference, the RX carrier power at each CS is assumed to be –70 dBm. This implies that, for this particular interference calculation where polarizations match, the two interfering carriers must be no closer than 3rd adjacent to support 4-QAM. Note also that the NFD values do not increase very much beyond 2nd adjacent.

Simulation results are quantified in the following clauses in terms of C/I distributions for three categories of radio elements: TDD CSs, TDD TSs, and FDD CSs. Some introductory comments on these distributions by category are provided here to aid in interpretation.

For the TDD CS C/I distribution, a total C/I value is calculated for each of the 100 TDD CSs. The total C/I value at a CS is determined by the net effect (see note 2) of potential interference from all other TDD CSs (always assumed to be LoS), all other TDD TSs (some paths are LoS and some are blocked), and all FDD CSs (always assumed to be LoS). Because the TDD CSs are exposed to the greatest number of interference mechanisms, their C/I values are not generally as high as those of the other radio elements. See annex C for details and assumptions for presenting and combining all potential interference sources into a total, net interference into a given victim radio element.

NOTE 1: If one channel frequency is in the lower spectral block, and the other channel frequency is in the upper spectral block, the NFD is assumed to be 75 dB, reducing the interference to –113,7 dBm. However, each individual case of TDD-FDD CS-CS interference necessarily involves a single TDD channel and a pair of FDD channels: outbound (FDD interferes into TDD) and inbound (TDD interferes into FDD). Since the FDD outbound channel will reside in the lower spectral block and the inbound channel will reside in the upper spectral block, a TDD channel can never be selected so as to achieve a 75 dB NFD relative to both channels in an FDD channel pair simultaneously.

NOTE 2: Recognizing that only one radio (the CS or one of multiple TSs) in a TDD sector is transmitting at any given time.

For the TDD TS C/I distribution, a total C/I value is calculated for each of the 1 080 TSs (total number of TSs remaining after winnowing). The total C/I value at a TS accounts for interference from all other TDD CSs (some paths are LoS and some are blocked).

For the FDD CS C/I distribution, a total C/I value is calculated for each of the 100 FDD CSs. Only the interference from the 100 TDD CSs (all CS-CS paths are LoS) is considered in this C/I calculation; no FDD intrasystem interference is simulated. Because of this, the reported FDD CS C/I values are generally much higher than those of the TDD system elements. This is artificial, of course, and it is noted that there can be multiple intrasystem FDD interference exposures at distances of ≈5R (14 dB). The purpose, here, however, is to determine and report the amount of interference that TDD CSs cause into FDD CSs.

10.2 No guard band, 100-meter offset

This clause provides a discussion of the simulation results for the case of no guard band - see figure C.6(a) for spectral relationships. All simulations start with the "Before QSAFA" frequency plan shown in figure C.7.

The first scenario is the "NE" 100-meter offset. The "Before QSAFA" and "After QSAFA" frequency plans are shown in figures C.7 and C.8. The "Before QSAFA" and "After QSAFA" C/I distributions are shown in figure C.9, and demonstrate that QSAFA improves the C/I distributions in all categories of radio element. The C/I distributions have bin sizes of 1-dB. For discussion purposes, results are summarized into some larger dB-ranges in tables 1 and 2. Values less than 19 dB will not support 4-QAM.

Table 1: "NE" C/I results *before* qsafa (no guard band)

Num. of each type of radio element within each C/I range	< 19 dB	19 dB to 24 dB	25 dB to 30 dB	≥ 31 dB
FDD CS	2	8	1	89
TDD CS	8	33	29	30
TDD TS				All 1 080 ≥ 35 dB

Table 2: "NE" C/I results *after* qsafa (no guard band)

Num. of each type of radio element within each C/I range	< 19 dB	19 dB to 24 dB	25 dB to 30 dB	≥ 31 dB
FDD CS				All 100 > 35 dB
TDD CS		15	11	74
TDD TS				All 1 080 > 35 dB

As far as TDD interference into FDD is concerned in this scenario, it has been reduced "After QSAFA" to the extent that the FDD CSs all have C/I ≥ 35 dB. It needs to be re-emphasized that although FDD CSs may be counted in the "≥ 31 dB" bin in tables 1 to 12, this is simply for the convenience of showing the amount of interference produced by TDD into FDD. This does not mean that the FDD CSs would have such high C/I values in reality. Remember that the FDD CS C/I values reflect only the interference caused by the TDD CSs and do not include their own intrasystem interference, which, as previously mentioned, may limit their C/I to 14 dB in some cases.

The TDD CS C/I situation has also been dramatically improved. The TDD TS C/I situation is largely unaffected because building blockage between TDD CSs and TDD TSs results in a low level of interference to begin with.

The remaining scenarios are "SE", "NW", and "SW", also using a 100-meter offset with no guard band. The "Before QSAFA" and "After QSAFA" C/I distributions are shown in figures C.10 to C.12, and all demonstrate that QSAFA improves the C/I distributions in all categories of radio element. Results are summarized below, in tables 3 to 8.

Table 3: "SE" C/I results *before* qsafa (no guard band)

Number of each type of radio element within each C/I range	< 19 dB	19 dB to 24 dB	25 dB to 30 dB	≥ 31 dB
FDD CS	8 (4 @ -4 dB)	1	2	89
TDD CS	8	33	32	27
TDD TS				All 1 080 ≥ 35 dB

Table 4: "SE" C/I results *after* qsafa (no guard band)

Number of each type of radio element within each C/I range	< 19 dB	19 dB to 24 dB	25 dB to 30 dB	> 31 dB
FDD CS				All 100 ≥ 35 dB
TDD CS		15	3	82
TDD TS				All 1 080 ≥ 31 dB

Table 5: "NW" C/I results *before* qsafa (no guard band)

Number of each type of radio element within each C/I range	< 19 dB	19 dB to 24 dB	25 dB to 30 dB	≥ 31 dB
FDD CS	8 (4 @ -4 dB)	1	2	89
TDD CS	7	34	30	29
TDD TS				All 1 080 ≥ 35 dB

Table 6: "NW" C/I results *after* qsafa (no guard band)

Number of each type of radio element within each C/I range	< 19 dB	19 dB to 24 dB	25 dB to 30 dB	≥ 31 dB
FDD CS			1	99
TDD CS		15	13	72
TDD TS				All 1 080 ≥ 36 dB

Table 7: "SW" C/I results *before* qsafa (no guard band)

Number of each type of radio element within each C/I range	< 19 dB	19 dB to 24 dB	25 dB to 30 dB	> 31 dB
FDD CS	2	8	1	89
TDD CS	8	33	29	30
TDD TS				All 1,080 ≥ 35 dB

Table 8: "SW" C/I results *after* qsafa (no guard band)

Number of each type of radio element within each C/I range	< 19 dB	19 dB to 24 dB	25 dB to 30 dB	≥ 31 dB
FDD CS				All 100 ≥ 36
TDD CS		15	2	83
TDD TS				All 1 080 ≥ 33 dB

10.3 One guard band, 100-meter offset

A guard band equal to one channel bandwidth was then inserted between the operators' spectral blocks, (see figure C.6(b) for spectral relationships - and the above simulations were repeated. For brevity, only the "after QSAFA" results will be shown here. The "after QSAFA" results for the "NE", "SE", and "SW" simulations are all very similar, so the "NE" results will be presented as representative of all three of these diagonal directions. For the "after QSAFA" C/I distributions see figure C.13.

Table 9: "NE" C/I results *after* qsafa (one guard band)
(also representative of "SE" and "SW" results)

Number of each type of radio element within each C/I range	< 19 dB	19 dB to 24 dB	25 dB to 30 dB	≥ 31 dB
FDD CS				All 100 ≥ 39 dB
TDD CS		15	1	84
TDD TS				All 1 080 ≥ 38 dB

It is interesting to compare the table 9 results above ("NE", with one guard band) with the table 2 results ("NE", no guard band) in the previous clause. The lowest values of C/I for FDD CSs and TDD TSs have improved by just 3 dB to 4 dB with the introduction of the guard band. More noticeably for the TDD CSs, the number of CSs in the 19 dB to 24 dB bin has remained the same, while ten CSs have moved from the "25 dB to 30 dB" bin to the "≥ 31 dB" bin. With this gross bin resolution, this looks like a significant amount of improvement for the TDD CSs but in reality it represents a shift of just a few dB across a bin boundary. For example, in table 2 in the previous clause, eleven TDD CSs fall into the "25 dB to 30 dB" bin, but a detailed examination reveals that nine of those C/I values are 29 dB to30 dB, so just 1 dB to 2 dB of improvement shifts them to the "≥ 31 dB" bin. The finer resolution of the C/I distributions in figure C.13 also shows that the improvement from adding a guard band (compare to figure C.9) does not result in a general 22-dB upward shift (difference between 1st adjacent and 2nd adjacent carrier NFD).

This amount of C/I improvement is perhaps less than one might initially expect from the addition of the guard band between the TDD and FDD operators. However, a likely explanation can be derived from analysis of:

- The 25 dominant TDD-FDD CS-CS proximate pairs in this simulation.
- The frequencies that QSAFA assigns to the TDD CSs involved in these pairs (and resulting interoperator frequency distances).
- The assumed values of NFD.

In the "NE" simulation in the previous clause, where no guard band is used, QSAFA has assigned frequencies to these particular TDD CSs in a way that creates "localized guard bands" (where needed) out of the TDD channel spectrum. For example, of the 25 proximate pairs in the "NE" scenario with no guard band, 15 pairs have the same polarization. Of these 15, there are 3 TDD CSs having frequency assignments with frequency distances ≥ 3 from the FDD inbound and outbound frequencies, and the remaining 12 TDD CSs have frequency distances ≥ 4. The NFD values are rather flat in this range of frequency distances, with NFD[3^{rd} adj.] = 51 dB, and NFD[≥ 4^{th} adj.] = 55 dB (see note 1). Assuming that the 15 proximate pairs that have the same polarization dominate the potential TDD-FDD interference environment, QSAFA has already done a good job in the "no guard band" scenario of mitigating this interference by using localized frequency separation where needed. Note that when a global guard band *is* inserted, then, following this same reasoning, it would be expected to cause only incremental (not major) C/I improvement based on the assumption that NFD[4^{th}] = NFD[5^{th}], etc. Obviously, different assumptions about the NFD values would affect these results to some extent (see note 2).

NOTE 1: 75 dB if the frequency distance spans lower and upper spectral blocks.

NOTE 2: Another factor limiting the upper range of TDD CS C/I values is the presence of TDD intrasystem interference.

As previously mentioned, when the four offset simulations were run with one guard band, the "NE", "SE", and "SW" results were all very similar. However, the "NW" scenario "After QSAFA" results had one TDD CS that dropped from the previously lowest C/I value of 19 dB to 17 dB. This particular case is reported in detail here for completeness. See figure C.14 for the corresponding C/I distributions.

Table 10: "NW" C/I results *after* qsafa (one guard band)

Number of each type of radio element within each C/I range	< 19 dB	19 dB to 24 dB	25 dB to 30 dB	≥ 31 dB
FDD CS				All 100 ≥ 38 dB
TDD CS	1	14	1	84
TDD TS		1		1 079 ≥ 35 dB

The above results are similar to table 9 with one exception: there is a single TDD intrasystem TS-CS interference pair that produces enough interference (in conjunction with FDD interference) to degrade one of the 100 TDD CSs to a C/I of 17 dB, below the 4-QAM requirement. The pair consists of the TDD CS in sector 18 and TDD TS #7 in sector 14 (8,8 km apart, but assumed to be LoS based on the random effect of the building blockage model). Both are using the same frequency and polarization. If only this single interference path is considered, then the TS and the CS each cause mutual interference resulting in a C/I of 21 dB (at each radio) during any time period when one radio happens to be transmitting while the other radio is receiving. This will be an intermittent occurrence in a TDD system, but the simulation program does not take time factors into account when computing C/I. In addition, the TDD CS also experiences interference from the FDD CS in sector 20, which individually would produce a C/I of 20 dB. Adding these two sources of interference into the TDD CS results in a total C/I of about 17 dB. As shown in figures C.9 to C.13, the lowest C/I value ("After QSAFA") for TDD CSs in all of the other simulations is 19 dB.

11 Simulation results for random 100 m to 300 m TDD-FDD cell offsets, no guard band

Another type of simulation scenario was performed to relax the rigidity of the fixed 100-meter diagonal offset scenarios discussed above. The FDD and TDD cells still essentially overlay each other in this scenario, but a random offset is introduced on a cell-by-cell basis, rather than using an entirely rigid grid translation of a fixed distance in a fixed direction.

The random offset procedure starts with the 25 FDD cells lying directly on top of 25 TDD cells, and goes through the grid, cell by cell, randomly offsetting each FDD cell relative to its corresponding TDD cell. For example, the first FDD cell is offset from its corresponding TDD cell by a random distance, uniformly distributed in the range of 100 m to 300 m, and in a random direction, uniformly distributed in the range of 0° to 360°. Then the same procedure is performed on the 2nd FDD cell relative to its corresponding TDD cell, and so on. In this manner, each of the 25 pairs of FDD/TDD cells has a random offset distance and direction that is independent of all others, as before the simulation starts with the "Before QSAFA" TDD frequency plan as shown in figure C.7. The resulting C/I distributions are shown in figure C.15, and details are provided in tables 11 to 12.

Table 11: "random offset" c/i results *before* qsafa (no guard band)

Number of each type of radio element within each C/I range	< 19 dB	19 dB to 24 dB	25 dB to 30 dB	≥ 31 dB
FDD CS	4	2	8	86
TDD CS	5	35	32	28
TDD TS				1,080 ≥ 35 dB

Table 12: "random offset" c/i results *after* qsafa (no guard band)

Number of each type of radio element within each C/I range	< 19 dB	19 dB to 24 dB	25 dB to 30 dB	≥ 31 dB
FDD CS			4	96
TDD CS		3	14	83
TDD TS				1 080 ≥ 35 dB

Again, these results show general C/I improvement after QSAFA. A somewhat different interoperator C/I balance resulted here, with FDD having some lower C/I values while TDD gained slightly compared to previous runs. This scenario was run twice more with different random seeds, and all results are similar to those above.

12 Conclusions

The C/I distributions in all scenarios have been improved by application of the QSAFA algorithm to the simulated interference environment, which is designed to inflict extremely stressful TDD-FDD CS-CS interference couplings in a 5 × 5 cell grid.

The effectiveness of the algorithm in these simulations is borne out by the modest improvement in results seen when one additional guard band is introduced. This demonstrates how the algorithm in effect re-introduces the necessary "localized" guard bands for these interference scenarios.

12.1 List of items subject to further study, which should be addressed in part 2 of the Technical Report

- "actual" methodology (e.g. "dynamic" behaviour of systems during deployment phases and of interferences (see note), actual figures for algorithm activation, how frequently the mechanism is activated, "average" assessment of "unsolved" cases), in view of possible introduction as a normative part in EN 301 213-3 [10];
- implementation issues that might influence the effectiveness of AFA regarding response times, stability of interference environment, constraints resulting from limited spectrum, impact on regulatory regimes etc.;
- to investigate to what extent the impact of the AFA "localized" guard bands should be accounted for in some manner when spectrum planning;
- to further investigate inter systems CS-TS scenarios and to what extent the current AFA simulations may lead to under-estimate/ignore or over-estimate some TDD system generated interferences;

- to double check the impact of the potential correlation between Tx (fixed) height and the distance from the CS with regard to the elevation (antenna pattern efficiency).

NOTE: Dynamic Behaviour of Interference: although the intention of AFA is "..to be an infrequent event consistent with the rate at which new hubs are added to the area.", the time for measurement of interference has to be restricted. The validity of this measurements is based on the assumption, that during this measurement period the maximum possible interference really occurs at a certain subband. If this basic assumption is not fulfilled, a wrong decision concerning the minimum interfered subband might be taken (e.g. the interference depends on rain attenuation and rain distribution over the total area, behaviour of ATPC, and - depending on the measurement principle - on the traffic transmitted via the interfering carriers).

Annex A:
Assumptions, sample link budgets, and antenna RPEs

- Frequency = 26 GHz, cell radius R = 3,6 km, rain region K.
- "Clear Sky" conditions are used in the simulations.
- FDD and TDD radio system parameters are the same.
- RX noise floor = -94 dBm.
- CS antenna gain = 19 dBi.
- TS antenna gain = 34 dBi.
- CS TX power = 24 dBm.
- TS TX power at 3,6 km = 9 dBm (15 dB ATPC at sector edge).
- TS TX power at smaller distances is reduced by proportional ATPC.
- 0,1 dB/km of atmospheric loss is included in path loss calculations.
- 90-degree sectors.
- V and H polarizations are assigned permanently in initial layout – cannot be changed by QSAFA.
- Eight TDD channels (carriers) are available (separated into two spectrum blocks: four low channels and four high channels).
- Any two CS sector antennas at a single cell site are a minimum of 20 feet apart.
- Net Filter Discrimination (NFD) values used in evaluating the interference environment for a given frequency assignment solution are as follows (first four values from TR 102 074 [11], table 2, ETSI type B Emissions Mask, 25 % Excess Bandwidth):
  - 27 dB for 1st adjacent carrier;
  - 49 dB for 2nd adjacent carrier;
  - 51 dB for 3rd adjacent carrier;
  - 55 dB for other adjacent carriers (4th, 5th, etc.) within the same spectrum block;
  - 75 dB for frequencies from two different spectrum blocks (high-low split). Channels 1 to 4 are in the lower spectrum block, and 5 to 8 are in the upper spectrum block.
- Initial frequency re-use plan is shown in figure 4.2.2 in [4], reproduced in part in the present document.
- All C/I values greater than 99 dB are reset to 99 dB.
- No TS-to-TS interference is considered in simulations.

Table A.1: Inbound Link Budget (using TS at sector edge)

TS TX Power (15 dB ATPC at 3,6 km)	9 dBm
TS Antenna Boresight Gain	34 dBi
3,6 km Path Loss (including 0,1 dB/km)	-132 dB
CS Antenna Boresight Gain	19 dBi
RX Power at CS	-70 dBm

Table A.2: Outbound link budget (using TS at sector edge)

CS TX Power (constant)	24 dBm
CS Antenna Boresight Gain	19 dBi
3,6 km Path Loss (including 0,1 dB/km)	-132 dB
TS Antenna Boresight Gain	34 dBi
RX Power at TS	-55 dBm

NOTE 1: TS at sector edge and the CS both have the same 43 dBm EIRP.

NOTE 2: TS TX power depends on the distance from the CS, and will be < 9 dBm if closer to the CS. By using proportional ATPC, all TSs in a sector produce the same power level at the CS.

NOTE 3: TSs closer to the CS will receive proportionally higher power.

The antenna RPEs (azimuthal only) used in the simulations are shown below (derived from [7]). The 90-degree CS sector antenna RPE has been modified from the IEEE BTS RPE Class 2 (alpha = 45°). The CS COPOL and XPOL plots have been revised to drop "linearly" from -35 dB to -45 dB over the 135 to 180 degree range (see figure A.1), instead of a flat –35 dB over this range. The TS antennas use the IEEE STS RPE Class 2 (alpha = 2°, see figure A.2).

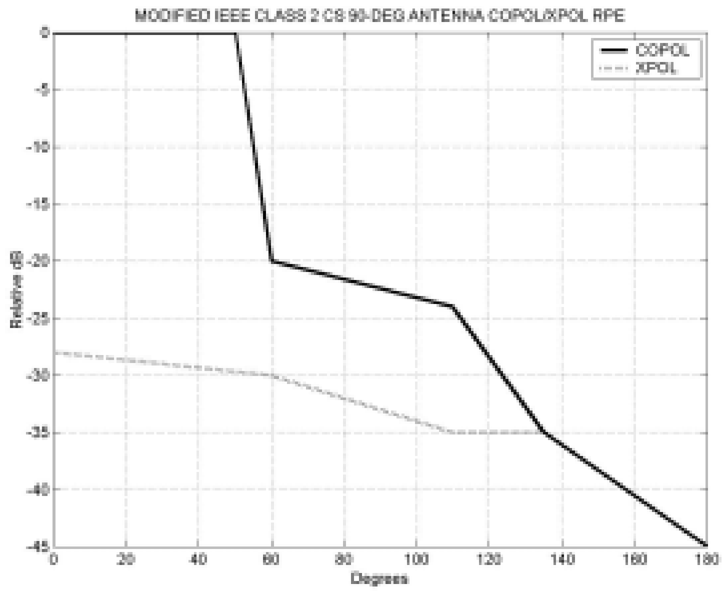


Figure A.1: IEEE class 2 CS antenna RPE

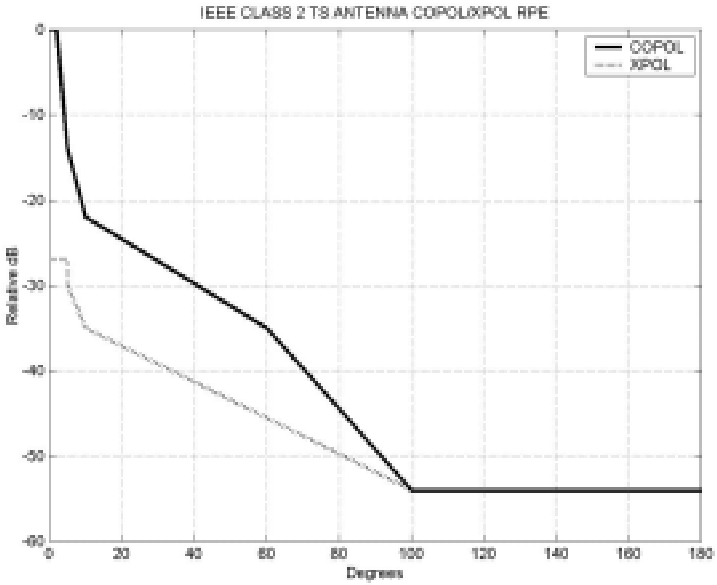
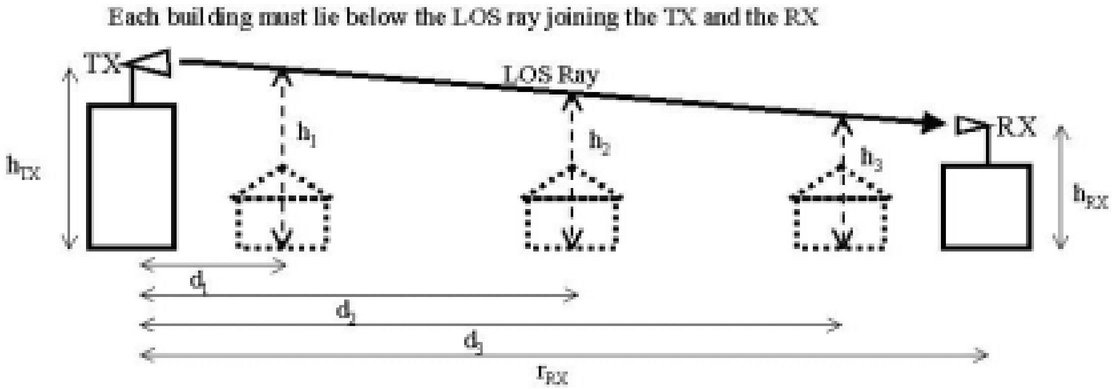


Figure A.2: IEEE class 2 TS antenna RPE

Annex B: "Rayleigh Rooftop" building blockage example derived from the CRABS report



The building heights h along the ray path are Rayleigh-distributed, such that:

$P(h) = (h / \gamma^2) \times \exp[- h^2 / 2\gamma^2]$, where $\gamma = 7{,}63$ m (mode of distribution).

For the ray to be LoS from TX to RX, at each building i the height h_i must be less than:

$h_{TX} - [d_i \times (h_{TX} - h_{RX}) / r_{RX}]$.

The number of buildings lying along a 1-km. path is:

- $b_1 = \alpha \mathrm{sqrt}(\beta)$, from [5], where:
  - $\alpha = 0{,}11$ (fraction of land area covered by buildings);
  - $\beta = 750$ bldgs / sq.km^2 (building density);
- or $b_1 = 3$ bldgs/km.

NOTE: Ref [6] uses $b_1 = \mathrm{sqrt}(\alpha\beta) = 9$ bldgs/km, which would increase the probability of building blockage.

The number of buildings lying along a r_{RX} km path is:

$b_r = \mathrm{floor}(r_{RX} \times b_1)$, where floor is used to ensure an integer number.

At each d_i, the probability P_i that a building is smaller than height h_i is given by:

$P_i = 1 - \exp[- h_i^2 / 2\gamma^2]$.

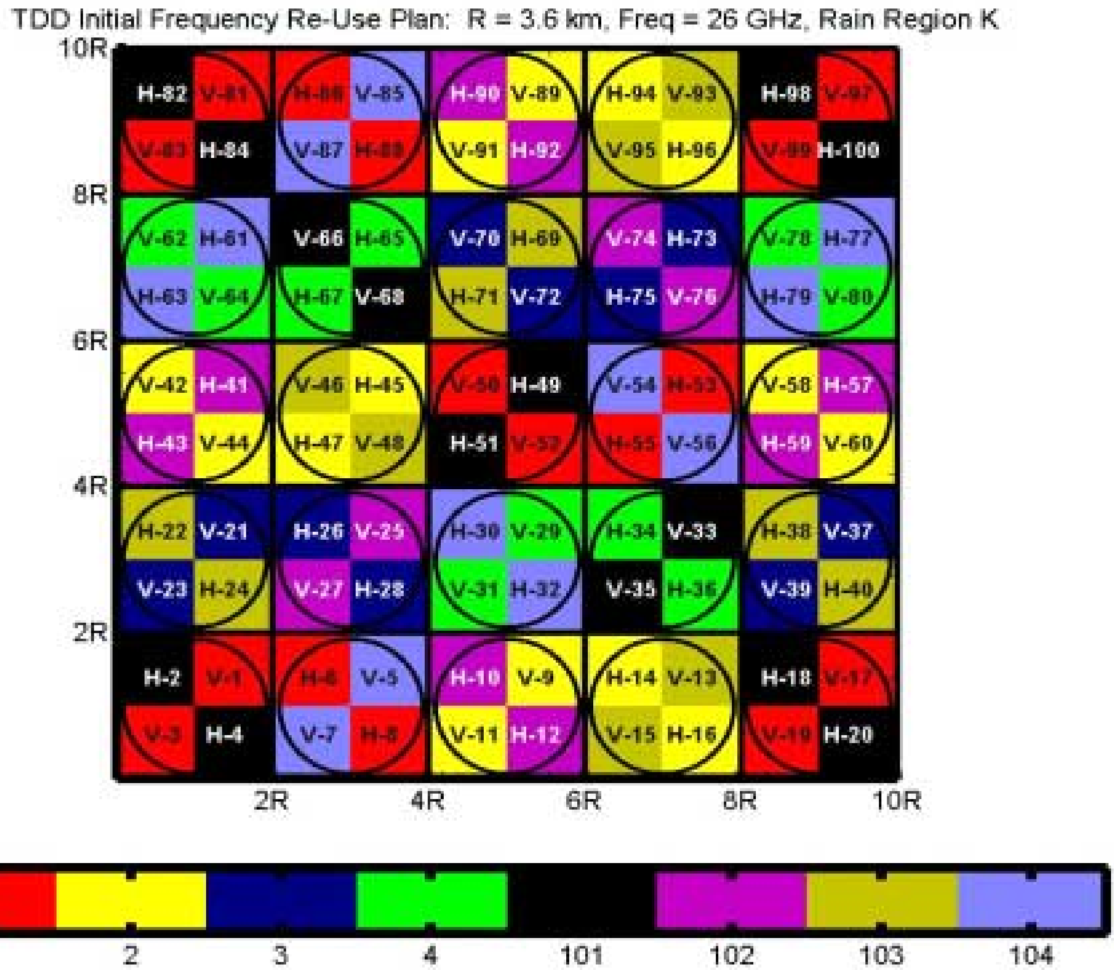
The probability that the ray is LoS across all intermediate buildings is the product of the individual P_i values.

For the example shown above, assume r_{RX} is 1 km, $h_{TX} = 30$ m, and $h_{RX} = 10{,}5$ m. The number of buildings crossed by the ray is 3 (using the more conservative estimate from the CRABS report (see Bibliography)), so the average distance between these buildings is 0,33 km. The buildings are assumed to be evenly spaced and positioned between TX and RX as shown. At each building, the calculated values are as in table B.1.

Table B.1: "random offset" c/i results *after* qsafa (no guard band)

i	d_i (km)	h_i (m)	P_i
1	0,167	26,75	0,9979
2	0,500	20,25	0,9705
3	0,833	13,75	0,8028
NOTE: The product of the P_i values = 0,7775, so there is a 78 % probability that the ray as shown is LoS.			

Annex C: Simulation, plan and results



Normalized Frequency

1 2 3 4 5 6 7 8

TDD Channel Number

Figure C.1: TDD initial frequency re-use plan, before QSAFA application

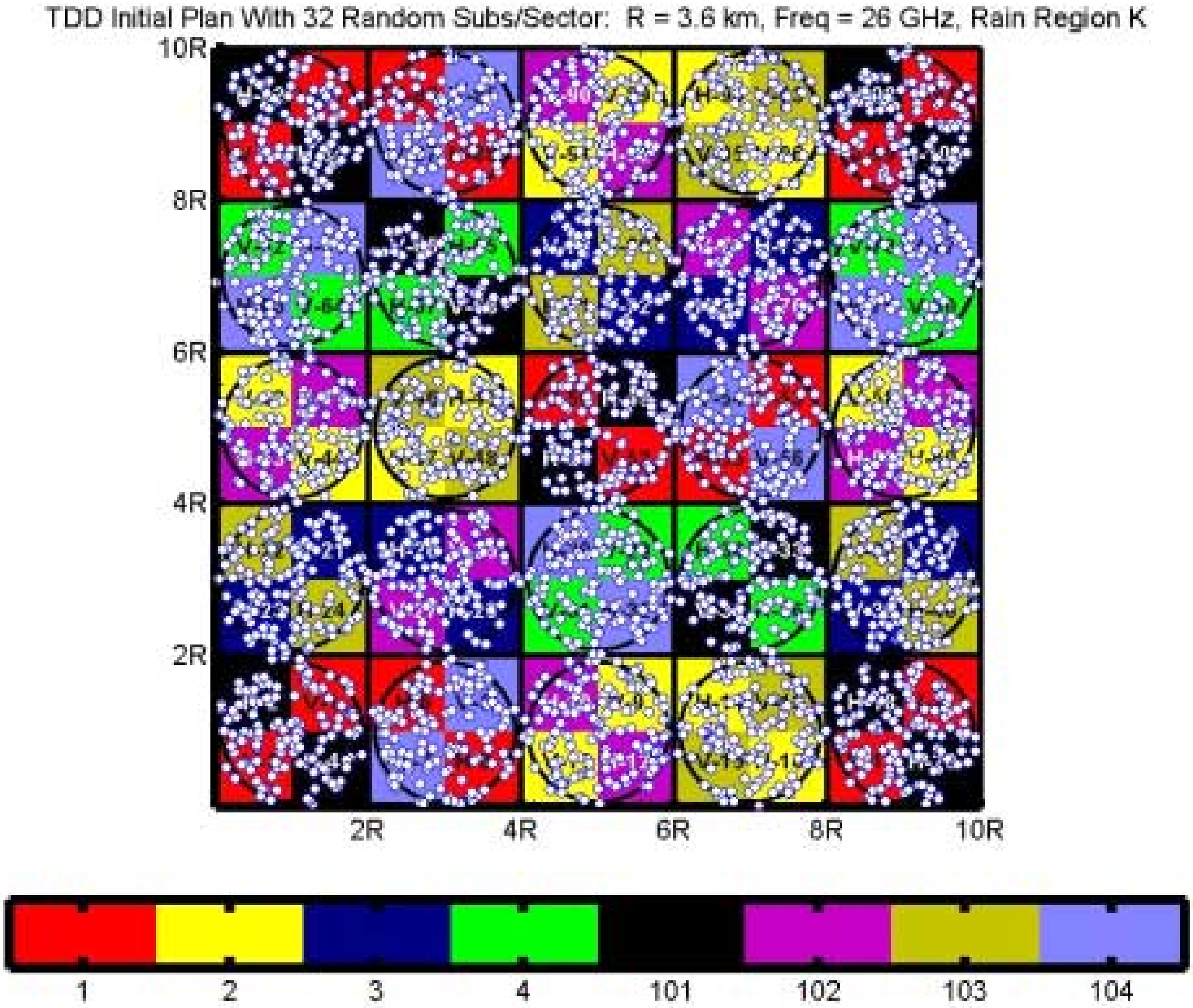


Figure C.2: Random placement of 32 TSs per sector

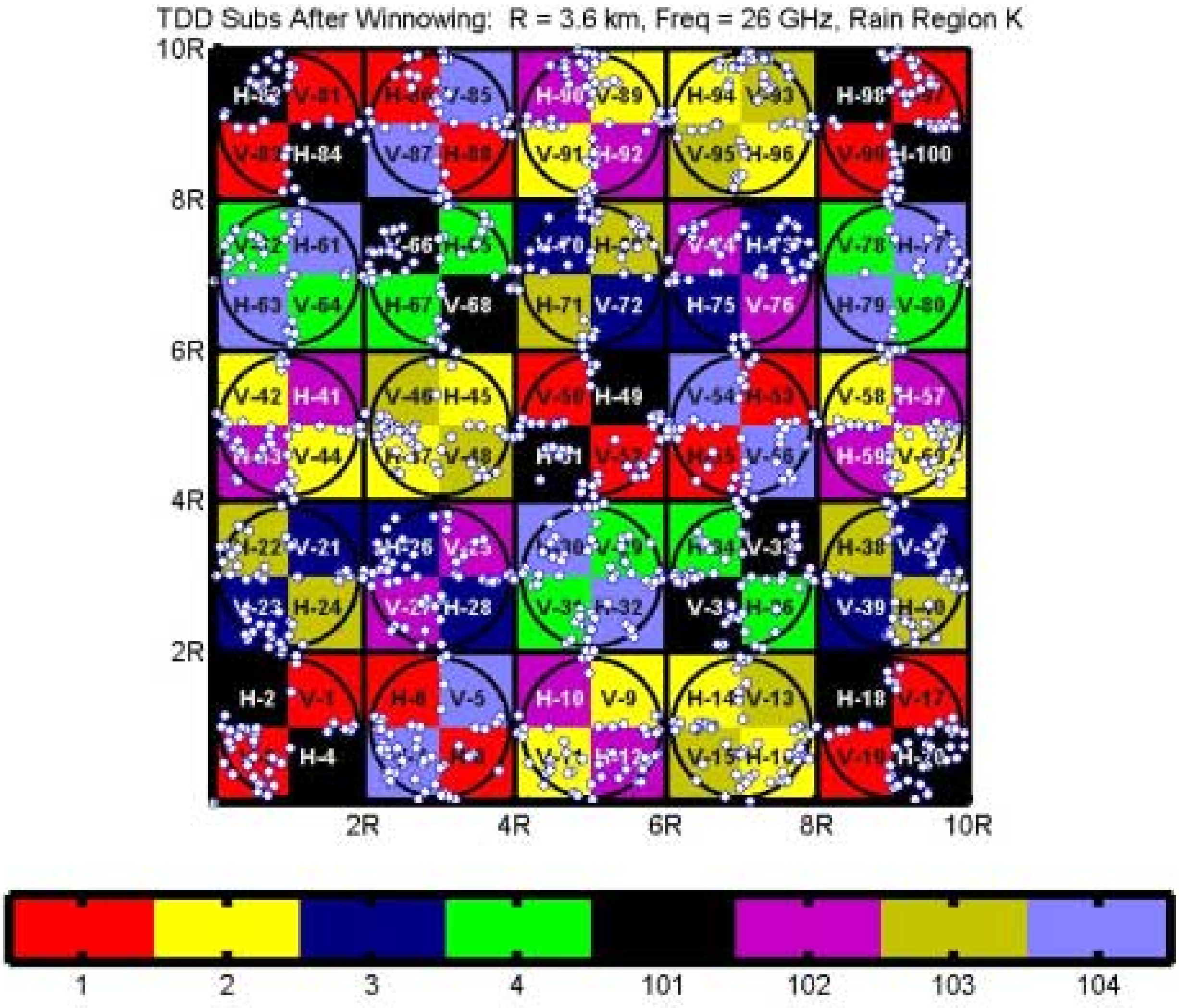


Figure C.3: Significant TSs remaining after winnowing

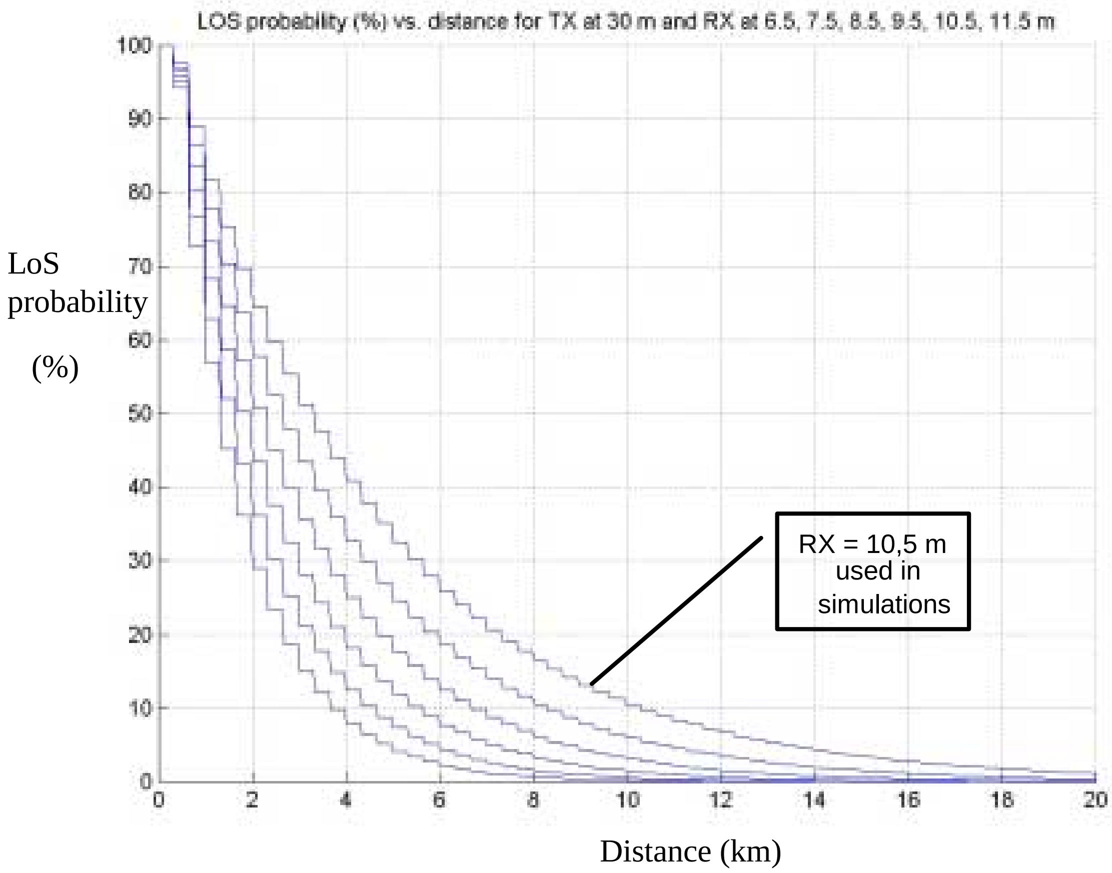
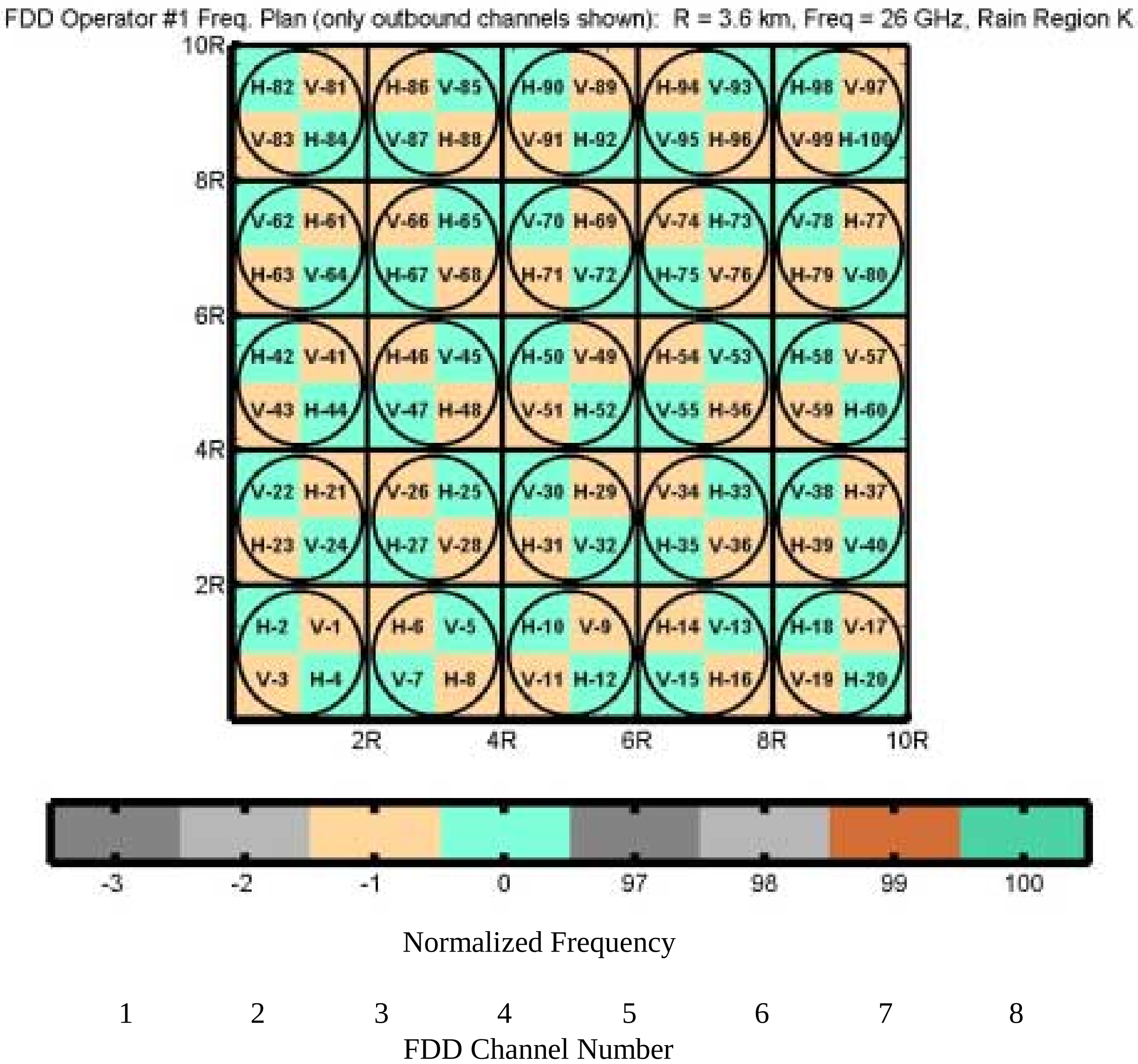


Figure C.4: Line-of-sight probabilities: Fixed TX height, varying RX height



NOTE: The normalized frequencies shown here correspond to the case where there is no guard band between TDD and FDD spectral blocks (see figure C.6(a)).

Figure C.5: FDD frequency re-use plan from a RAWCON presentation

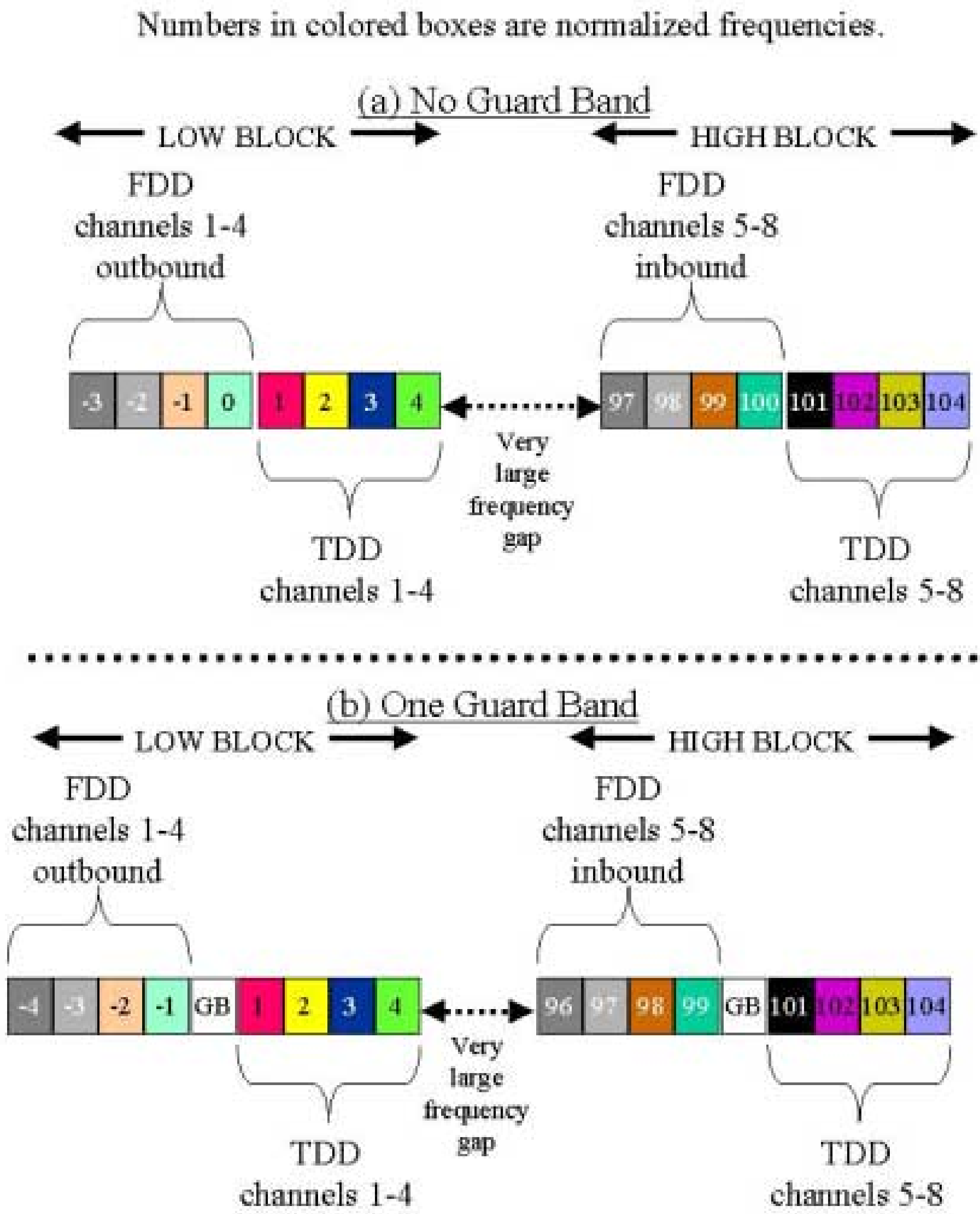


Figure C.6: TDD/FDD channel frequency relationship

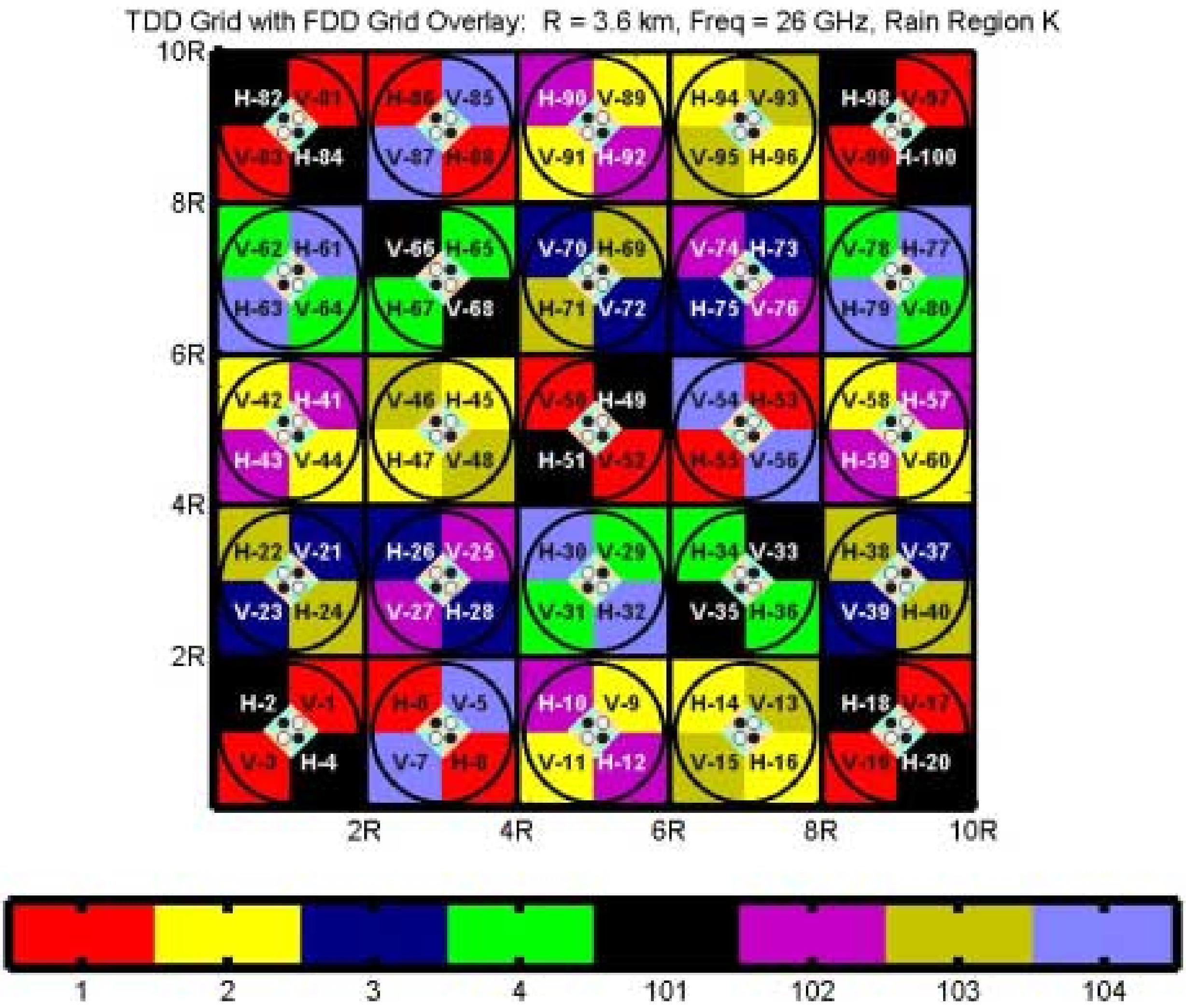
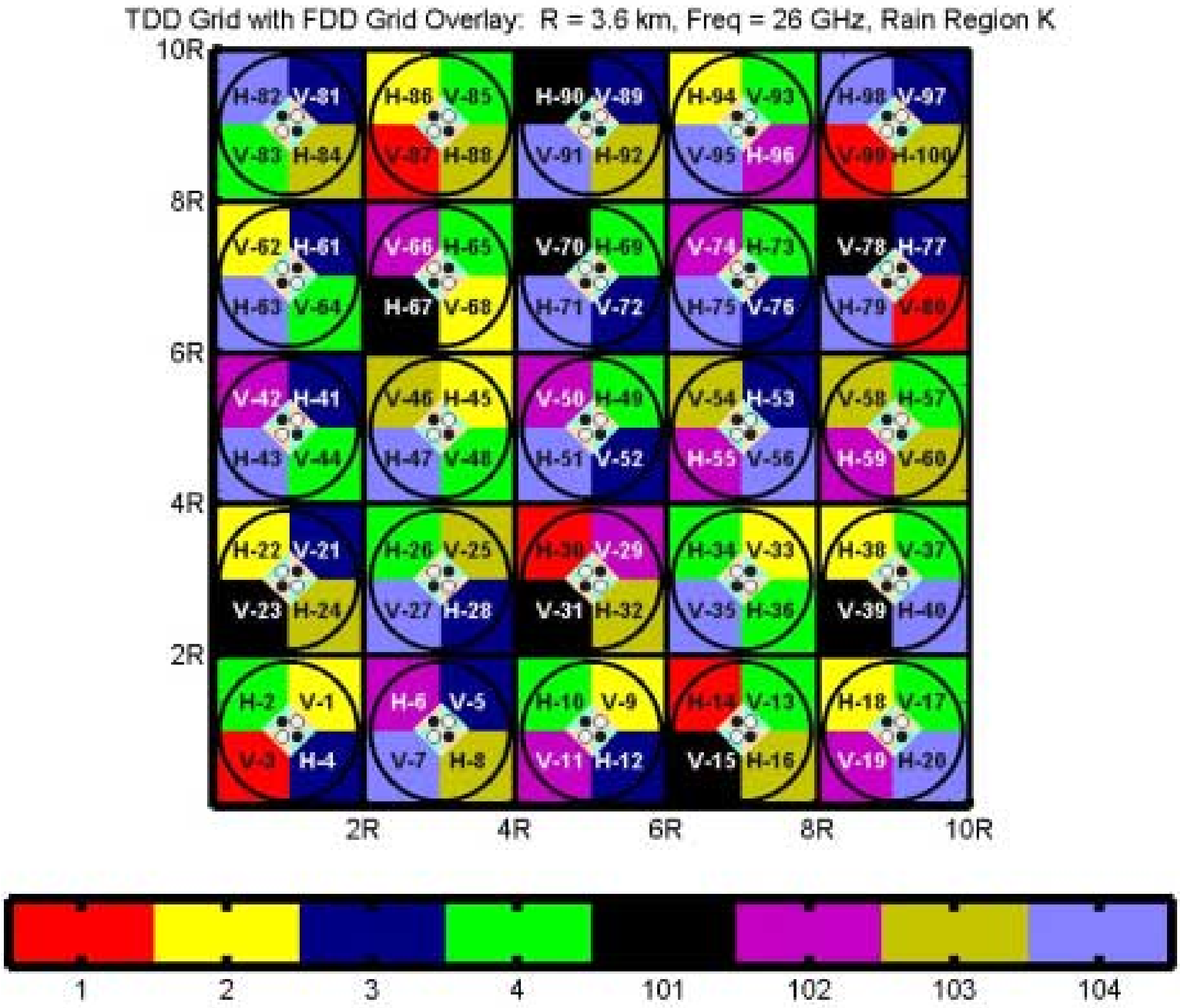
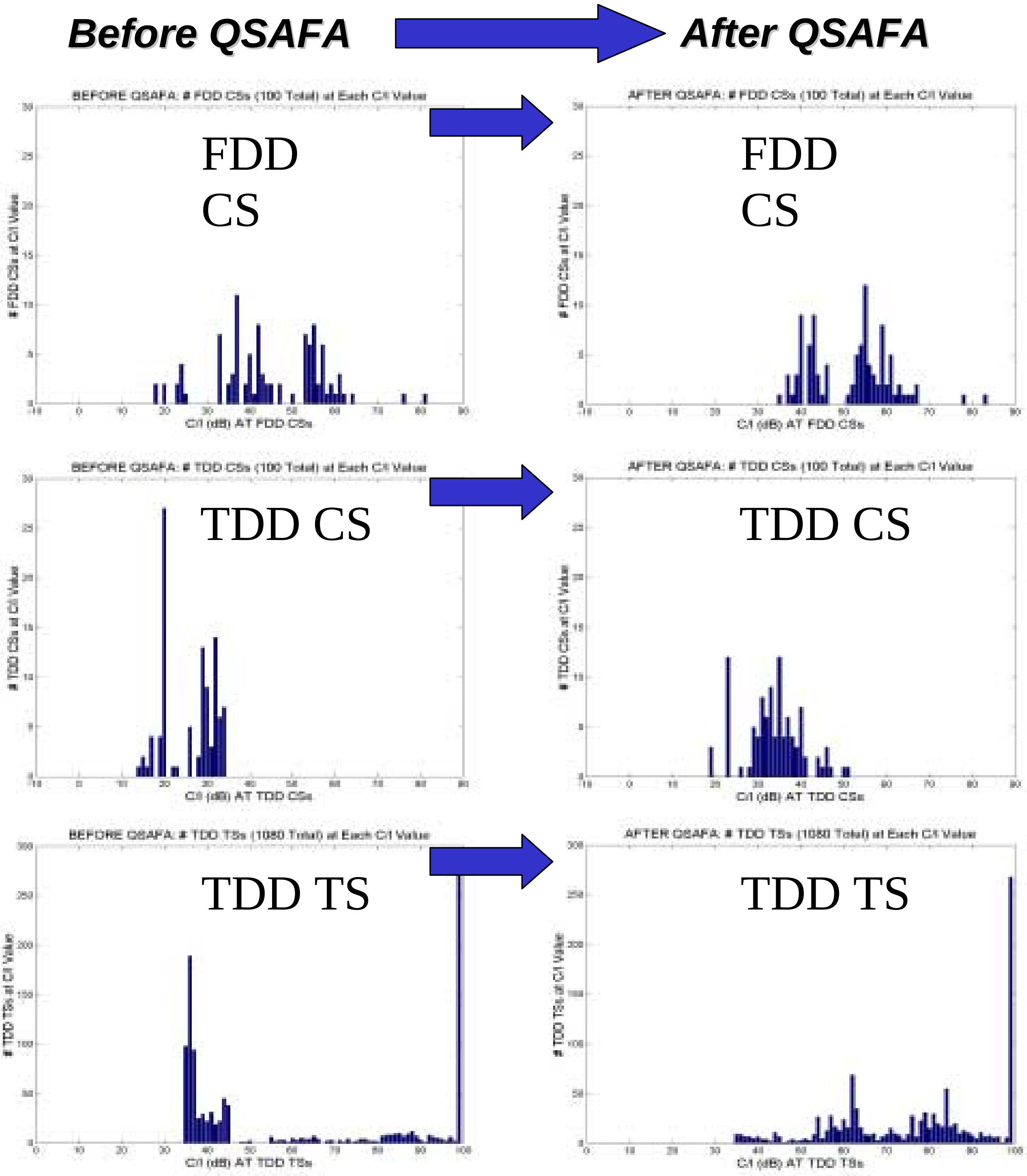


Figure C.7: Overlay of FDD cell grid on TDD cell grid, before QSAFA application



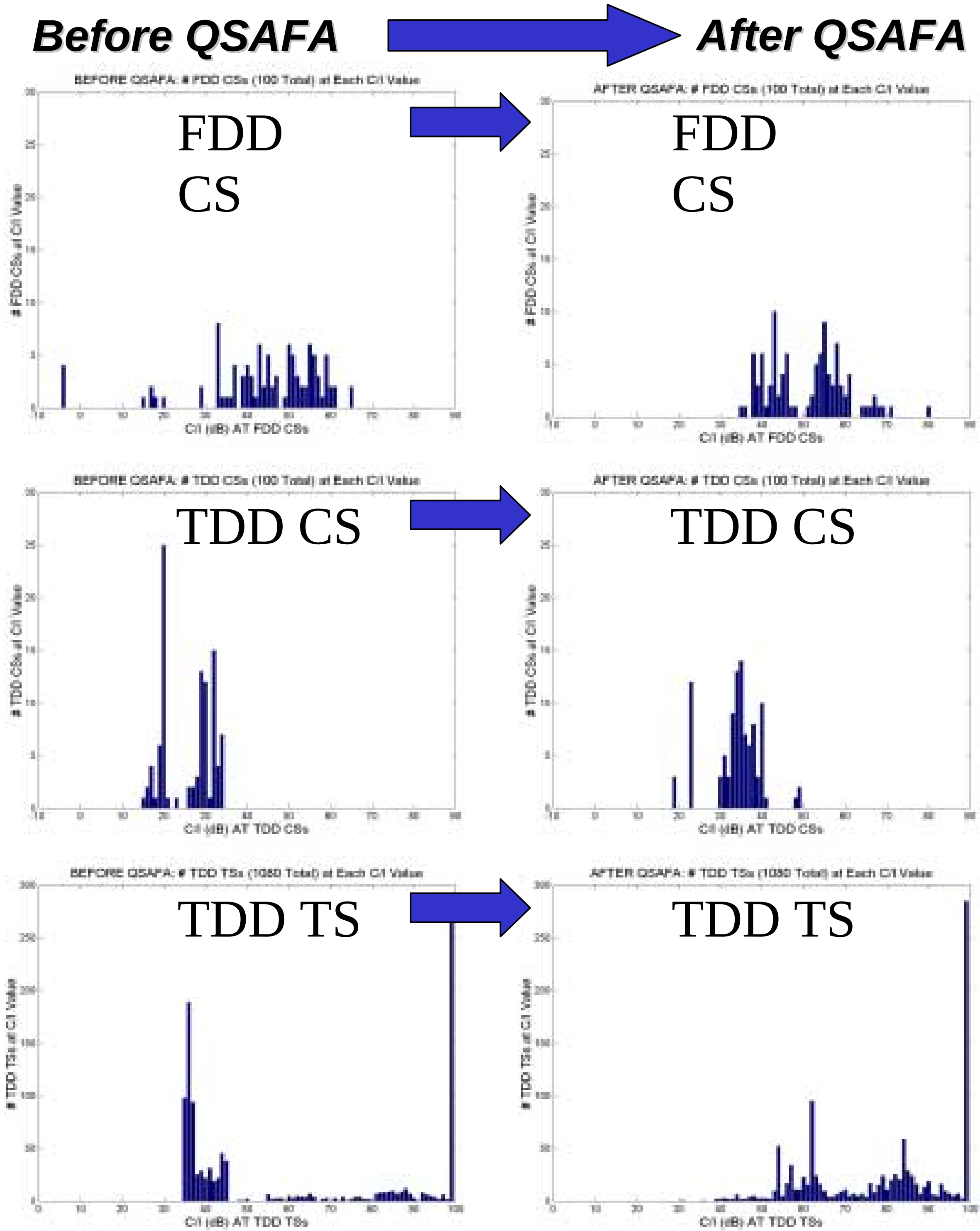
NOTE: FDD grid has 100-meter "NE" offset, no guard band.

Figure C.8: TDD frequency plan after QSAFA application



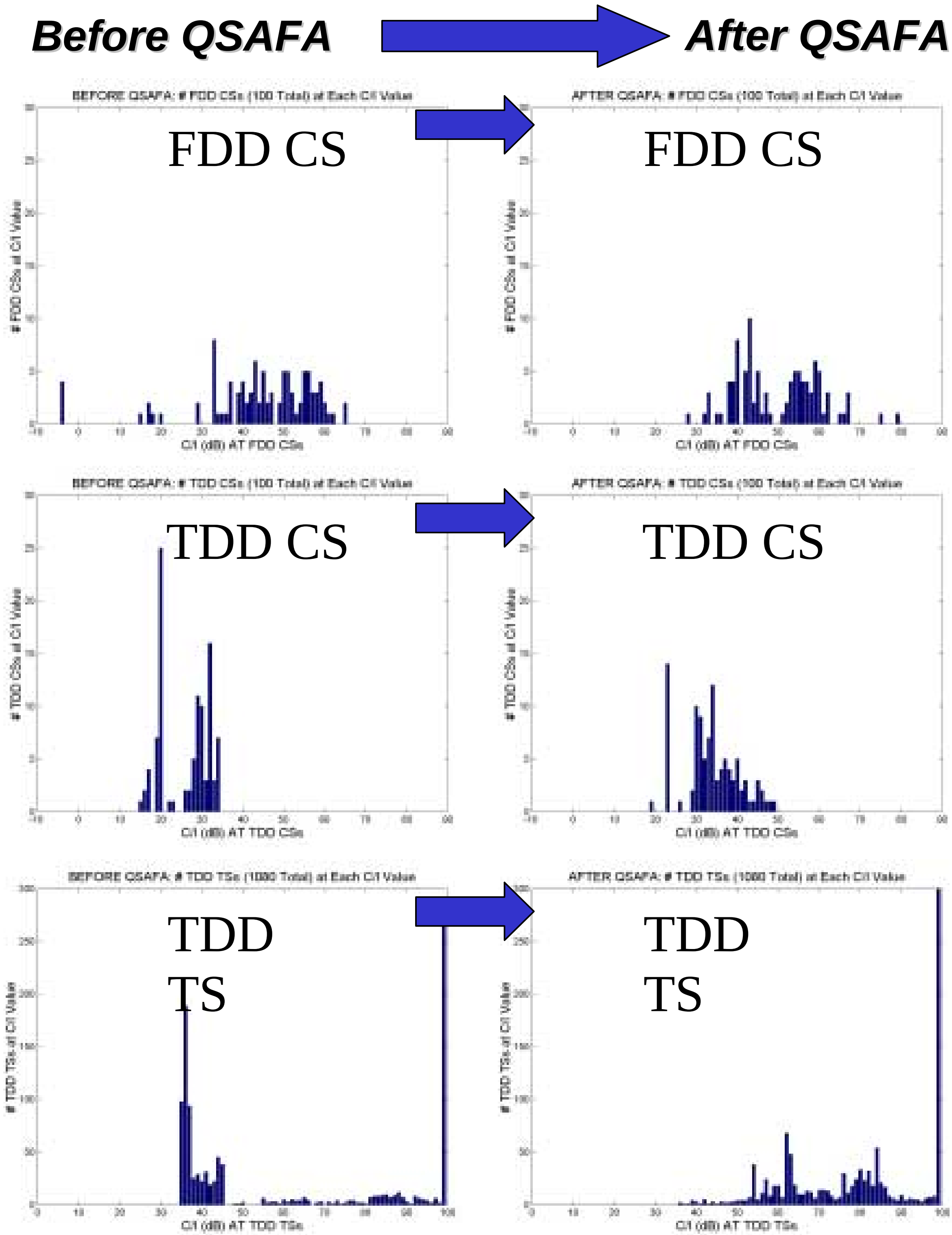
NOTE: TDD TS-CS building blockage model is used.

Figure C.9: C/I distributions: "NE" 100-meter offset, no guard band



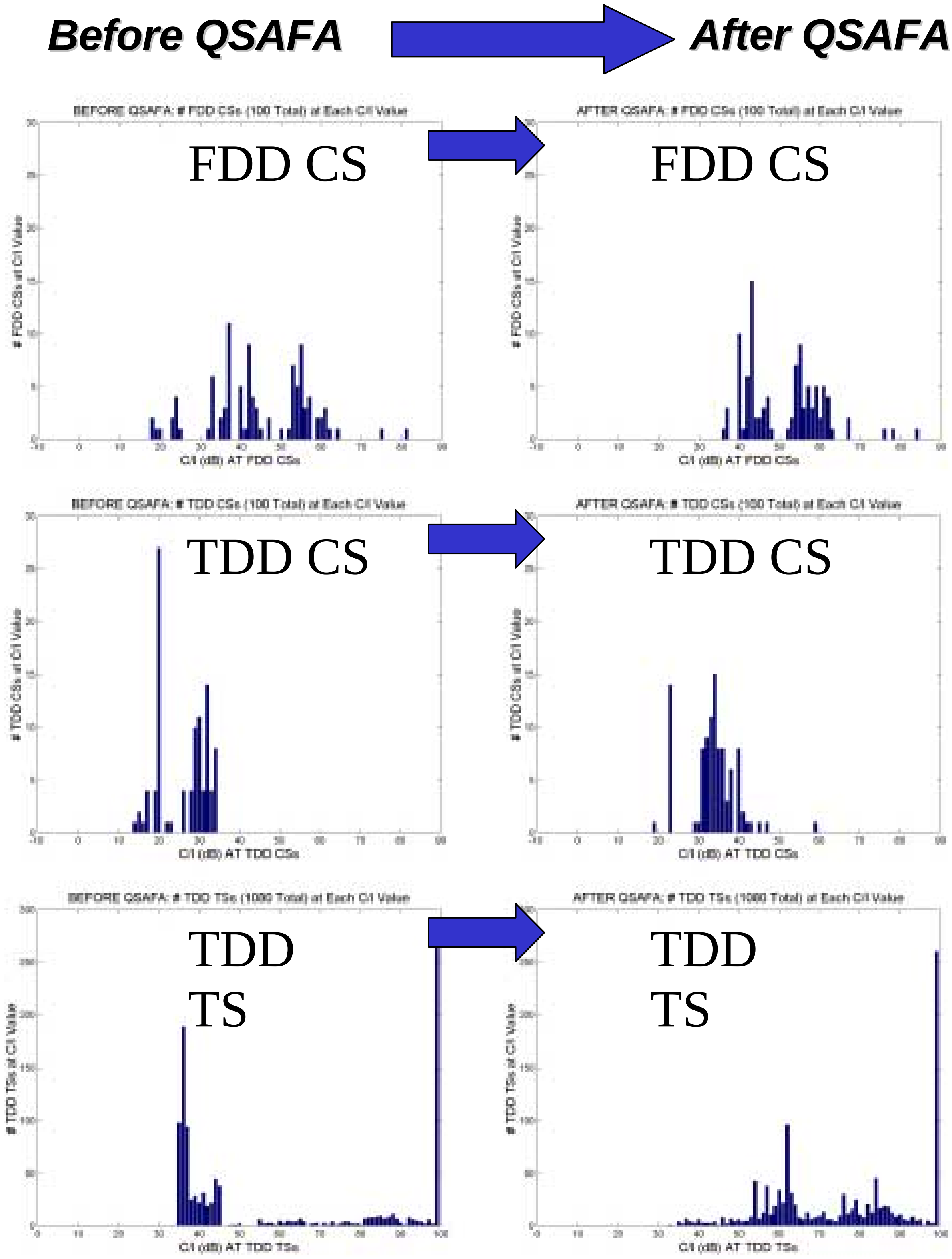
NOTE: TDD TS-CS building blockage model is used.

Figure C.10: C/I distributions: "SE" 100-meter offset, no guard band



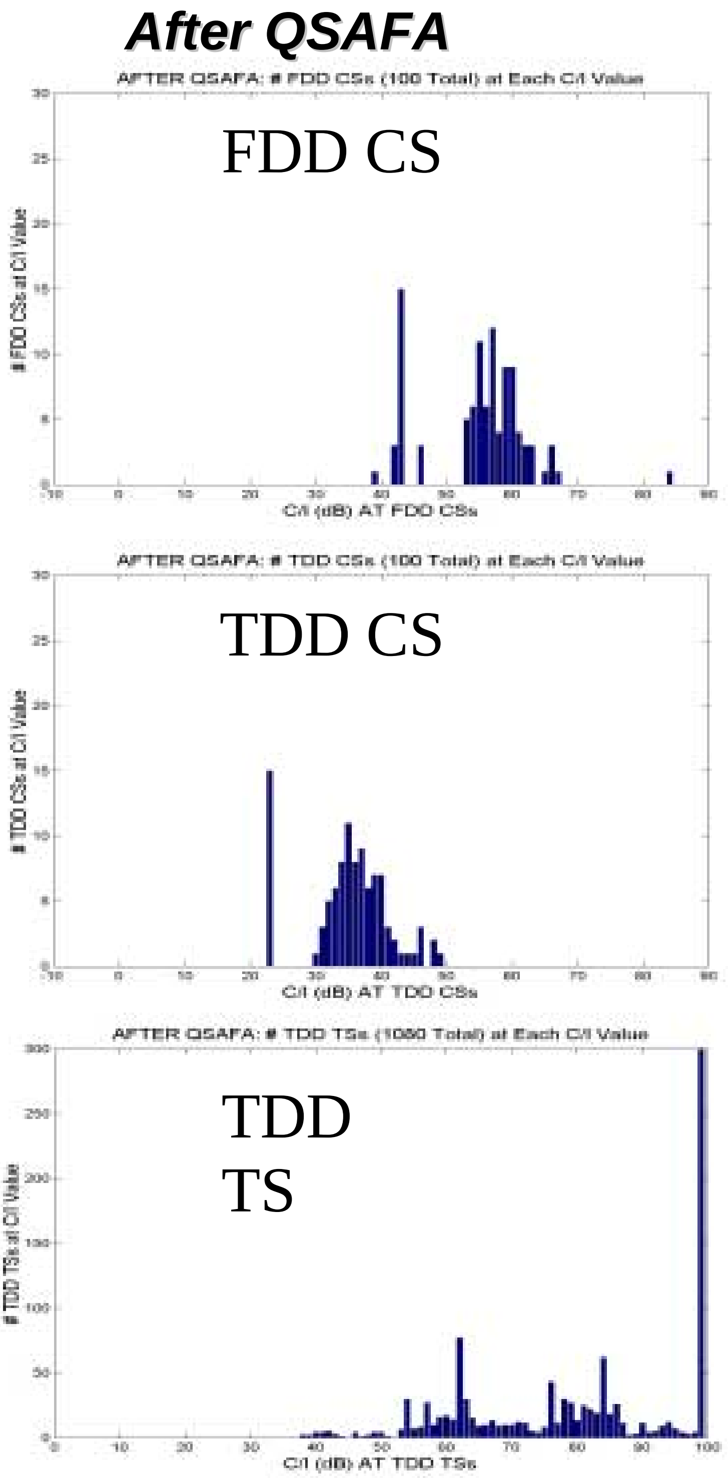
NOTE: TDD TS-CS building blockage model is used.

Figure C.11: C/I distributions: "NW" 100-meter offset, no guard band



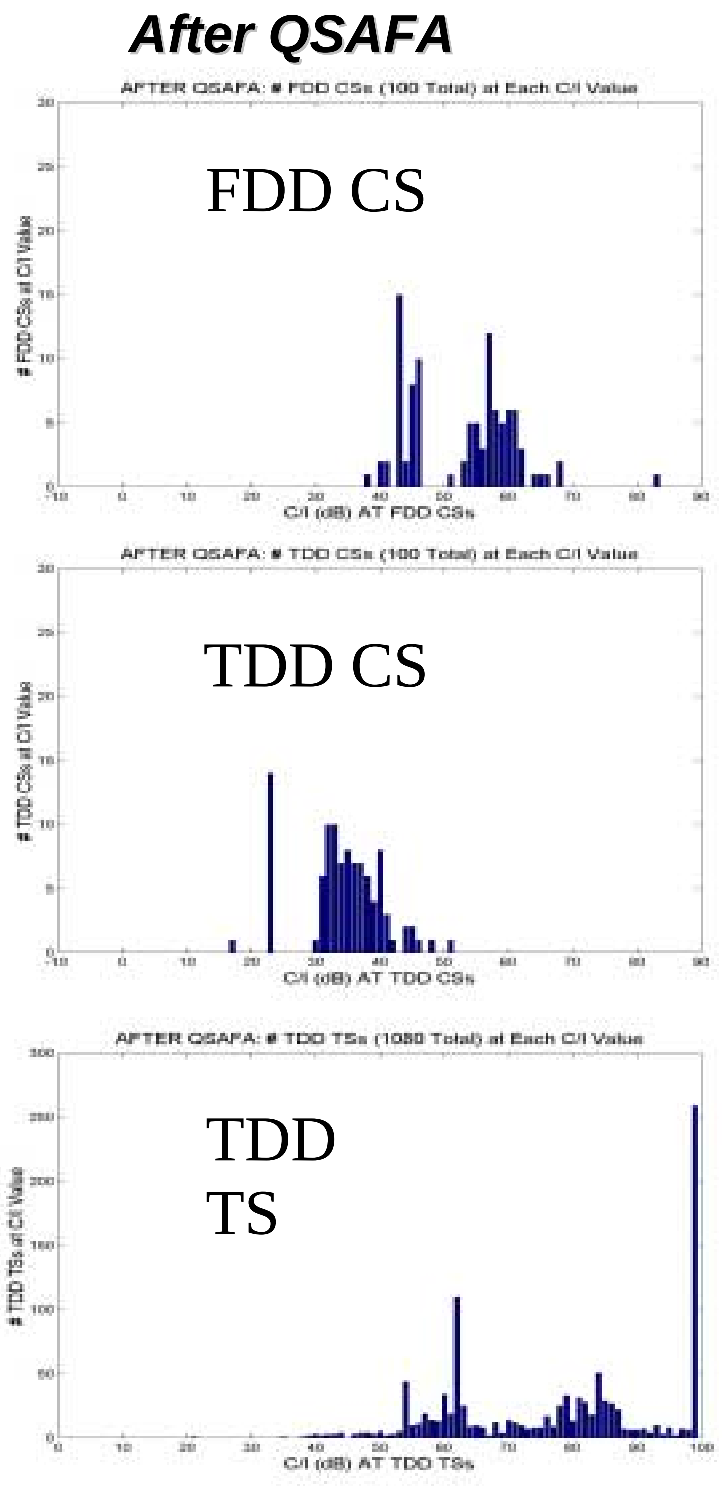
NOTE: TDD TS-CS building blockage model is used.

Figure C.12: C/I distributions: "SW" 100-meter offset, no guard band



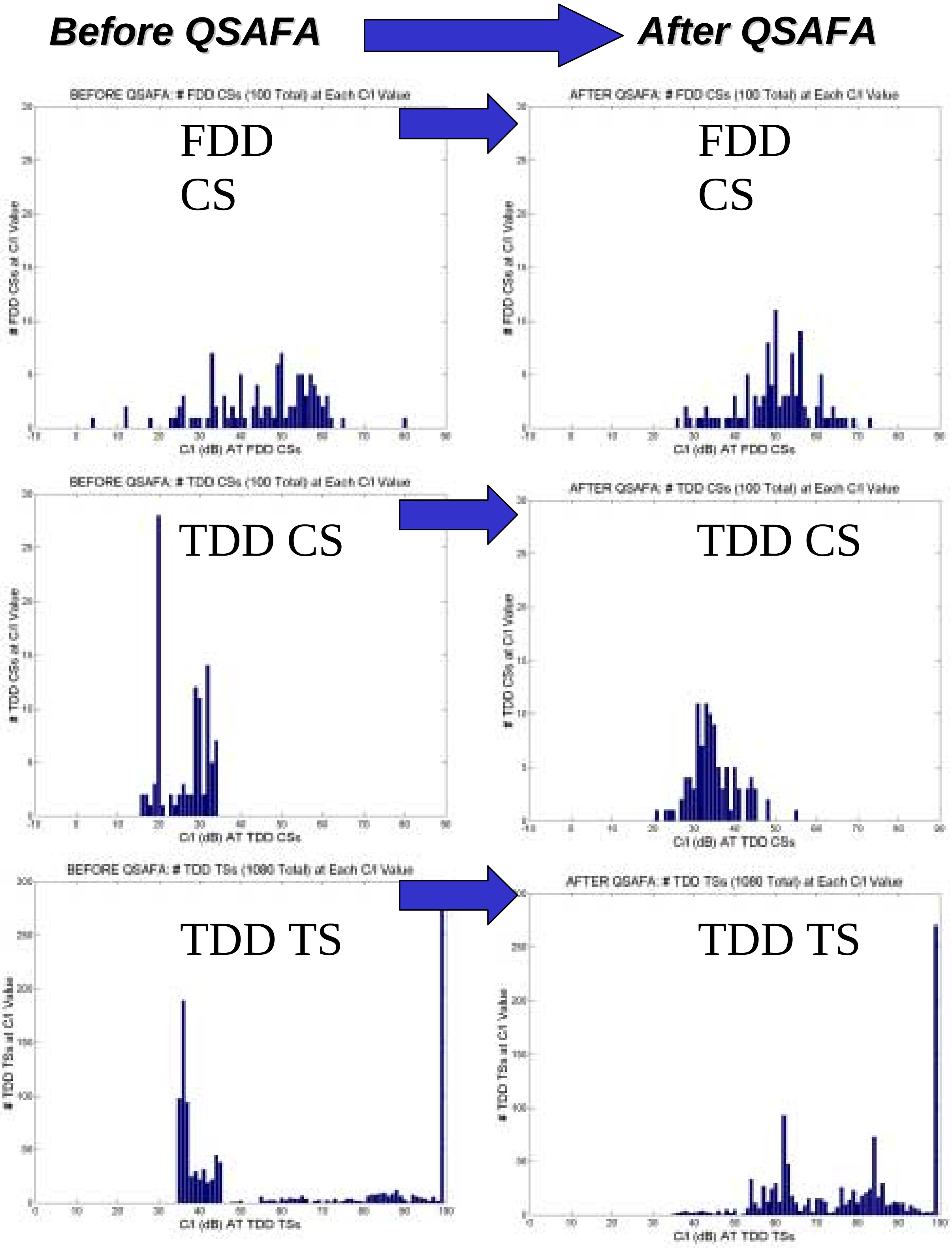
NOTE: TDD TS-CS building blockage model is used.

Figure C.13: C/I distributions: "NE" 100-meter offset, one guard band (also representative of "SE" and "SW")



NOTE: TDD TS-CS building blockage model is used.

Figure C.14: C/I distributions: "NW" 100-meter offset, one guard band



NOTE: TDD TS-CS building blockage model is used.

Figure C.15: C/I distributions: Random 100 m to 300 m offset, in random direction, no guard band

Annex D: Bibliography

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History

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