IBS Testing Pocket Guide: Part 1

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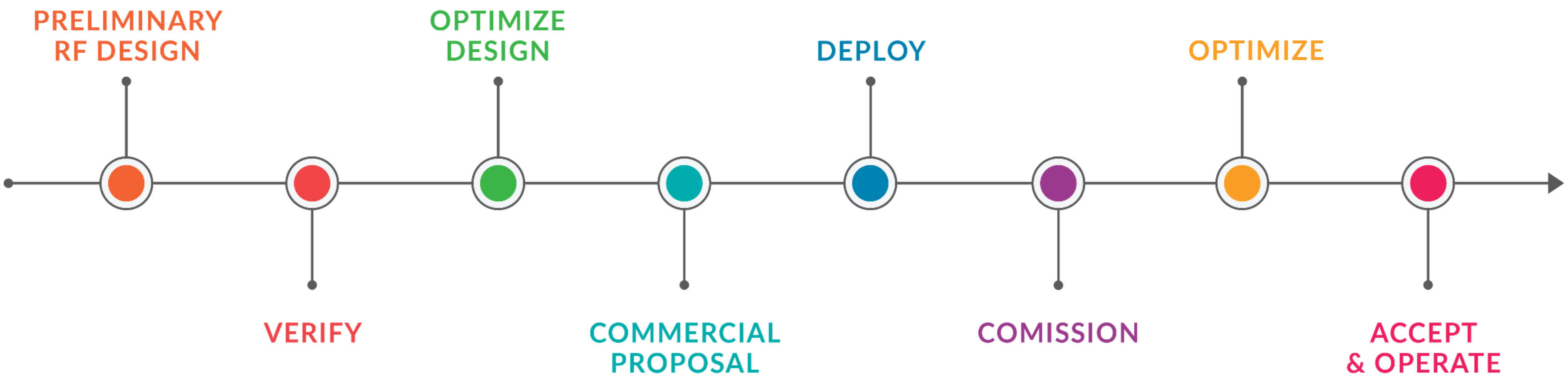
Introduction

Test and Measurements play a vital role in enhancing IBS site's quality and optimizing implementation Cost, hence helping businesses deliver reliable communication infrastructure with profitability and short delivery time.

Test procedures span the complete lifecycle of IBS Projects. From the moment the designer receives floor layouts of the building, planning for design verification takes place. Additionally, propagation model calibration and advanced testing can also take part. By the time the site has been implemented, commissioning and acceptance tests are performed. And testing continues in the operation phase as well.

To be able to understand the IBS testing requirements, a fair understanding of different IBS technologies and how they are implemented is required. In this guide we will explore the typical IBS site lifecycle and the test setups related to each phase of an In-Building site from design, implementation to maintenance and operations. We will also introduce some advanced test procedures for performance optimization, coverage benchmarking, troubleshooting and monitoring



IBS Site **Life Cycle**

IBS Overview

In-building Systems refers to a category of systems used to deliver reliable coverage for indoor subscribers. That includes Distributed Antenna Systems (DAS), Small-Cells and BDA's.

A typical IBS project will go through three major phases; Design, Implementation, and finally Operation. The details and milestones of each phase can vary from place to another according to contractual differences and depending on who performs the design or implements the system.

Each of these phases has its own test and measurements procedures serving a specific goal for the successful delivery of the IBS system

Design Phase:

In the design phase the designer performs several tasks to produce an implementable design that can deliver the required KPI's. Typically, a preliminary design will be created using RF design software followed (or preceded) by RF surveys. For some complex RF environments, the designer may perform advanced tests to optimize the design before submitting it.

Design verification tests at this stage prevent costly consequences of design errors and reduce unneeded design margins that may -unnecessarily- increase the project installation and operational cost.

To understand the importance of design margins, a well-known rule of thumb is that an additional 3 dB in signal level is in reality double the RF power. This can translate into doubling of RF Signal sources in extreme cases [1]. In reality the addition (or reduction) of design margins will always result in a considerable increase (or reduction) of RF equipment and can influence the project delivery and operations cost afterwards. Hence, RF Design verification is very important to learn exactly how much design margin is adequate above the required KPIs. Therefore, optimizing

[1] There are many approaches to redesign and achieve higher (or lower) signal levels given the site is in the design phase. However, it might be the case where additional signal power is required to be injected into the existing DAS site. At such extreme cases the RF equipment will increase significantly with marginal increase of coverage levels

the design and avoiding over-design or under-design situations.

Deployment Phase:

IBS deployment covers all IBS system and subsystems construction from structured cabling, electrical supply system, air-conditioning and other related works.

Several RF measurement procedures are required during this stage to test the quality of all RF and structured cabling installations.

Following a predefined testing process helps streamlining the project implementation and acceptance.

Operation Phase:

By the Time the site has been accepted, responsibility of its performance is transferred to the Operations and Maintenance teams. It can undergo periodic tests on the live network RF signal or offline (where the system is taken offline in maintenance time frame). The level of testing of the infrastructure and service may vary during operational phase depending on the importance of the Venue and other commercial considerations. In general MNO tends to prefer live network measurements that reflects end user experience and then might conduct advanced troubleshooting if a significant degradation is reported

Maintenance guidelines from DAS equipment manufacturers should be followed which can vary from vendor to another. A certain level of equipment availability and status monitoring can be obtained by the active equipment. More advanced RF availability reporting and testing can be performed on the Antenna level using distributed sensors.

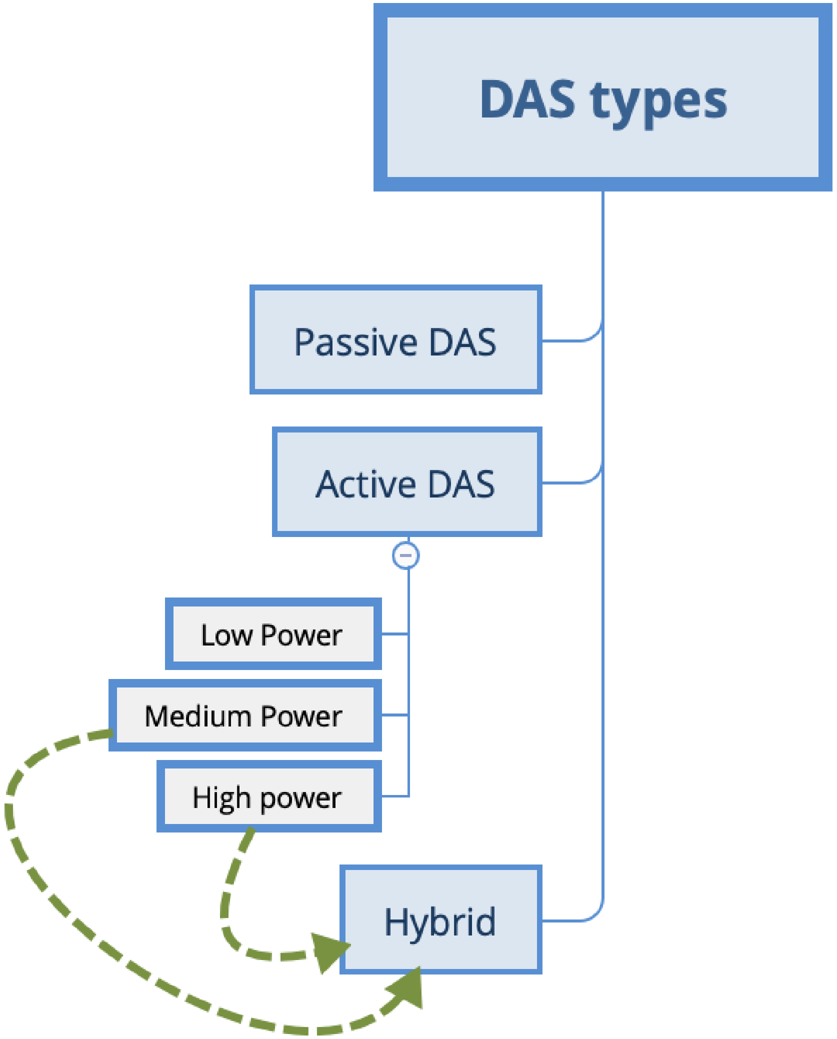


Figure 1 DAS classification.

Types of DAS

DAS can be classified into two major categories: Passive DAS and Active DAS. Passive DAS system utilizes a dedicated indoor Base Transceiver Station (BTS) to distribute its signal to multiple indoor antennas using a passive distributing network. Passive network is formed of Coaxial cables, equal and non-equal power splitters. On the other hand, active DAS system distributes the signal through amplification of the signal electronically on the forward and reverse paths, utilizing optical fiber, network cables and other types of low-loss physical media to deliver better signal with the target of achieving better quality of service. The combination of active and passive DAS is often referred to as Hybrid DAS which can be considered a third category.

Active DAS mainly solves three coverage problems that legacy macro-cellular, dedicated indoor BTS and Femto-cells cannot solve; 1) Indoor site with a low number of subscribers but with a wide coverage area that requires more power than what a typical dedicated BTS can provide. 2) A second example is the other extreme; a high number of subscribers in a relatively small coverage area with limited space to host the required equipment for such high concentration.

3) Finally when some Active DAS equipment comes with a solution for a third problem where quick and easy deployment is required due to physical limitations and aesthetic considerations.

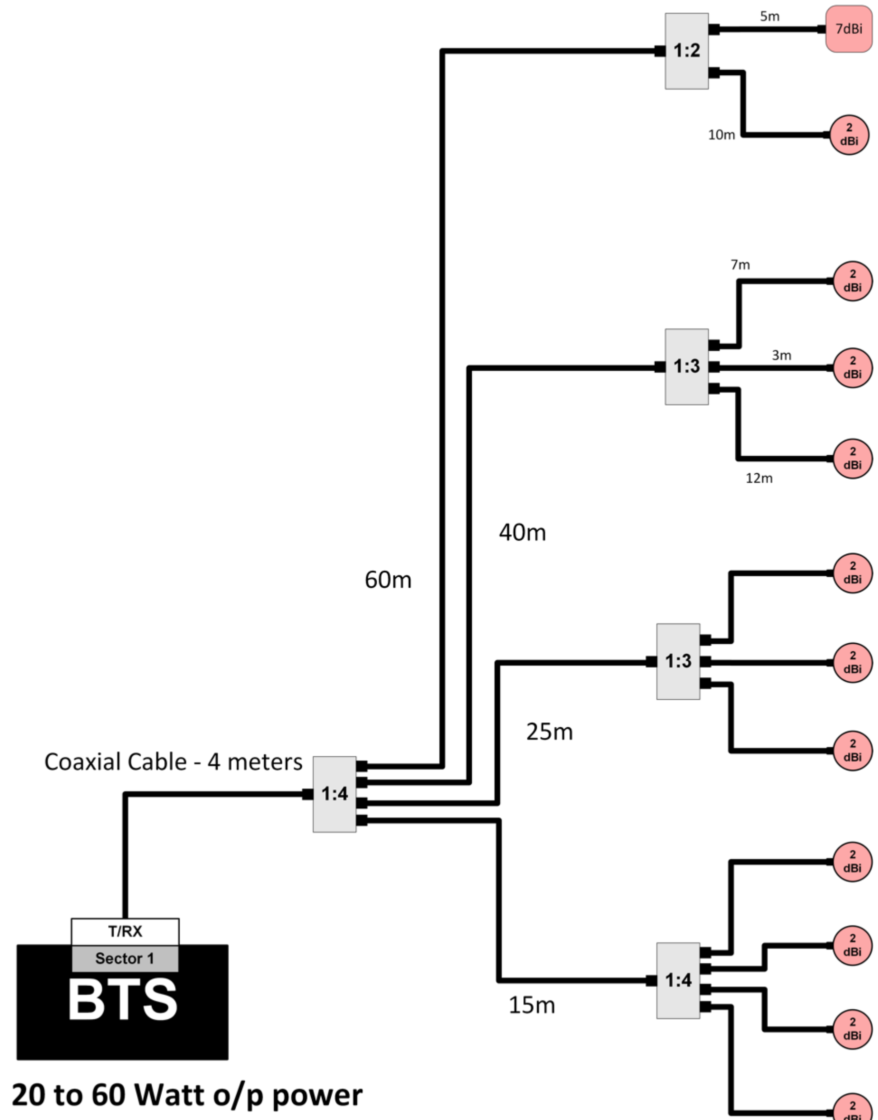


Figure 2 Passive DAS

	Measurement-Based Deign	Reasonable 3D wall model	Detailed 3D wall model
3D wall model	None	Approximated	Very Detailed
Design Time	Lowest	Average	Time consuming
Measurement effort	All Antennas	Overall Verification for different propgation environments	Overall Verification for different propgation environments
Assumptions	No Assumptions	3D Model and Wall Types	3D Model and Wall Types
Ideal for	Towers of Typical floors	Any Venue	Large and Complex venues
Confidence	Highest	Average	Average
Why we need to verify Coverage	• Actual Coverage foot print for all antennas	• Account for 3D model Approximation • Calibrate Empirical Model Parameters	• Empirical Model Parameters • Wall Material type • Avoid Wall Material selection errors

Figure 3 Different RF design Approaches

Different RF Design Approaches

IBS RF designs can have a wide variation in terms of tools, methods and details. RF design tools can be as simple as a link-budget spreadsheet or an advanced RF simulator with wall database and 3D models. Depending on designers preferred approach, the one thing in common to all of these approaches is the need to validate the design and perform measurement. Table 1 provides a summary of what can go wrong if designs deviate from optimum quantities.

Measurement-based design:

An approach where designs are made based on actual coverage measurements. No RF coverage prediction is involved in this process.

This approach reduces time consumed in drawing and optimizing wall models and provides the highest confidence in design, hence leaving no chance for prediction errors.

Extremely Detailed 3D wall model:

Requires a significant effort in detailing the model to reduce errors of approximations. Such approach provides very good prediction results given that wall types are carefully selected to match the actual walls and also wall loss parameters have to identical to the real material.

Software tools providers implement algorithms to calibrate wall losses and propagation model parameter based on field measurements.

In between these two design approaches is a full spectrum of possibilities where designs vary in wall details and RF verification details, nevertheless, an overall coverage measurement is the common factor for all design types. With more verification required for some designs based on the design assumptions.

RF Design Assumptions

Some assumptions must be verified with the proper Field measurement to avoid potential failures. These assumptions can also be viewed as sources of errors in RF design, such as:

Walls:

Selection of wall types is a human decision that can be very expensive if the wrong type was chosen. A lower loss material may result in better coverage prediction than actual. On the other hand, selecting a material of higher loss than reality -which can be seen as a safer approach- will always result in an IBS with better coverage than predictions, however, it will be at the expense of higher project cost and can also result in Performance degradation.[2]

Even for correctly selected wall types, the actual wall loss parameters may vary depending on Wall-finish.

Wall thickness as well may vary gradually in typical floors between topmost and lowermost floors, for example, High-rise buildings will have thicker columns on the lower floors than higher ones

Such details are impractical to take into account when building wall models for predictions. The best way to take them into account is by adding a reasonable and validated design margin.

Propagation model Empirical parameters

For computation speed optimization, deterministic coverage prediction model such as Ray Tracing can have some parameters that are rather empirical but not deterministic. Empirical parameter values are based on previous measurements of similar propagation environments.

[2] RF isolation between sectors influence soft hand-off regions and SINR values. For high density sites where multiple sectors exists, it is very important to have the proper wall losses to avoid RF interference between RF sectors

An RF designer should make sure such parameters are applicable to the particular environment in question and do not accept the default values without verification.

Waveguiding effect in tunnels is an example of such cases where the coverage may vary significantly depending on tunnel finish material, reflection and absorption characteristics. CW testing is very important to verify the coverage for car parks, trains, lift shafts, atriums and inclined surfaces.

Antenna footprint and Coverage overlap is important to verify for complex venues such as stadium to optimize the design before implementation.

Table 1 Non-optimized design consequences

Under-Design	Over-Design
Site does not meet Coverage KPIs Possible Contractual Penalties	Possibility to fail in Performance KPIs due to interference Possible Contractual Penalties
Costly retrofitting of DAS. Specially for Passive Network	Unjustified project cost paid by Infrastructure owner. Higher OPEX. More hardware → Higher energy bill
Unhealthy profit margins, if not operating at loss	Risk of losing a bid due to uncompetitive pricing
Damaging the service integrator Image	Damaging the service integrator Image (if unveiled).
	Chances of spillage and challenges on Macro networks for optimization. Highrise tower spillage becomes a huge radiating element causing higher pilot pollution.

RF Design Verification and Optimization Tests

In this section of the guide, test procedures for the IBS will be explained in details. Figure 5 shows an overall testing summary aligned with the IBS project lifecycle.
Throughout this section we will use the symbols in Figure 4 to refer to the test equipment utilized along the section.

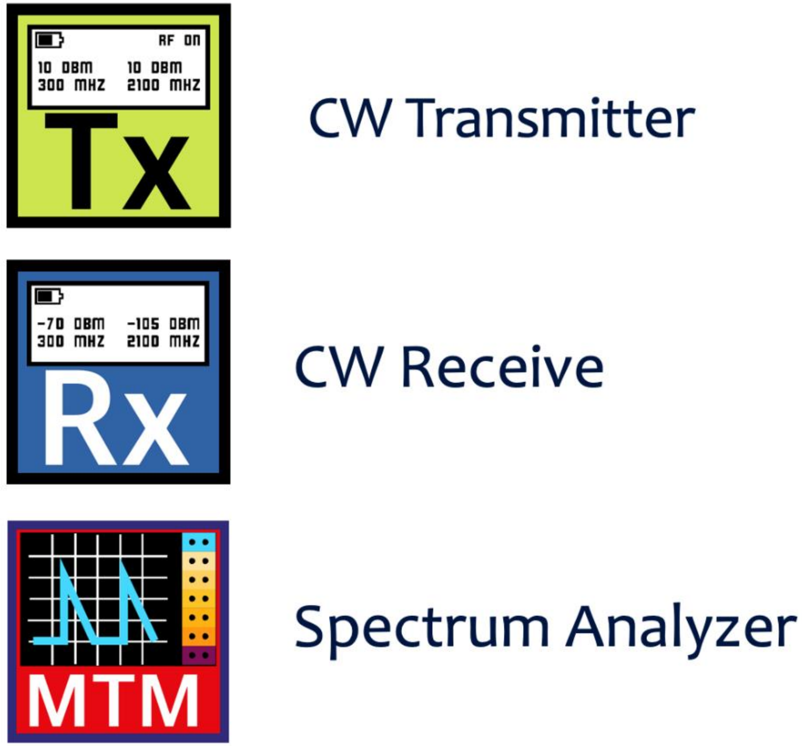


Figure 4 Legend

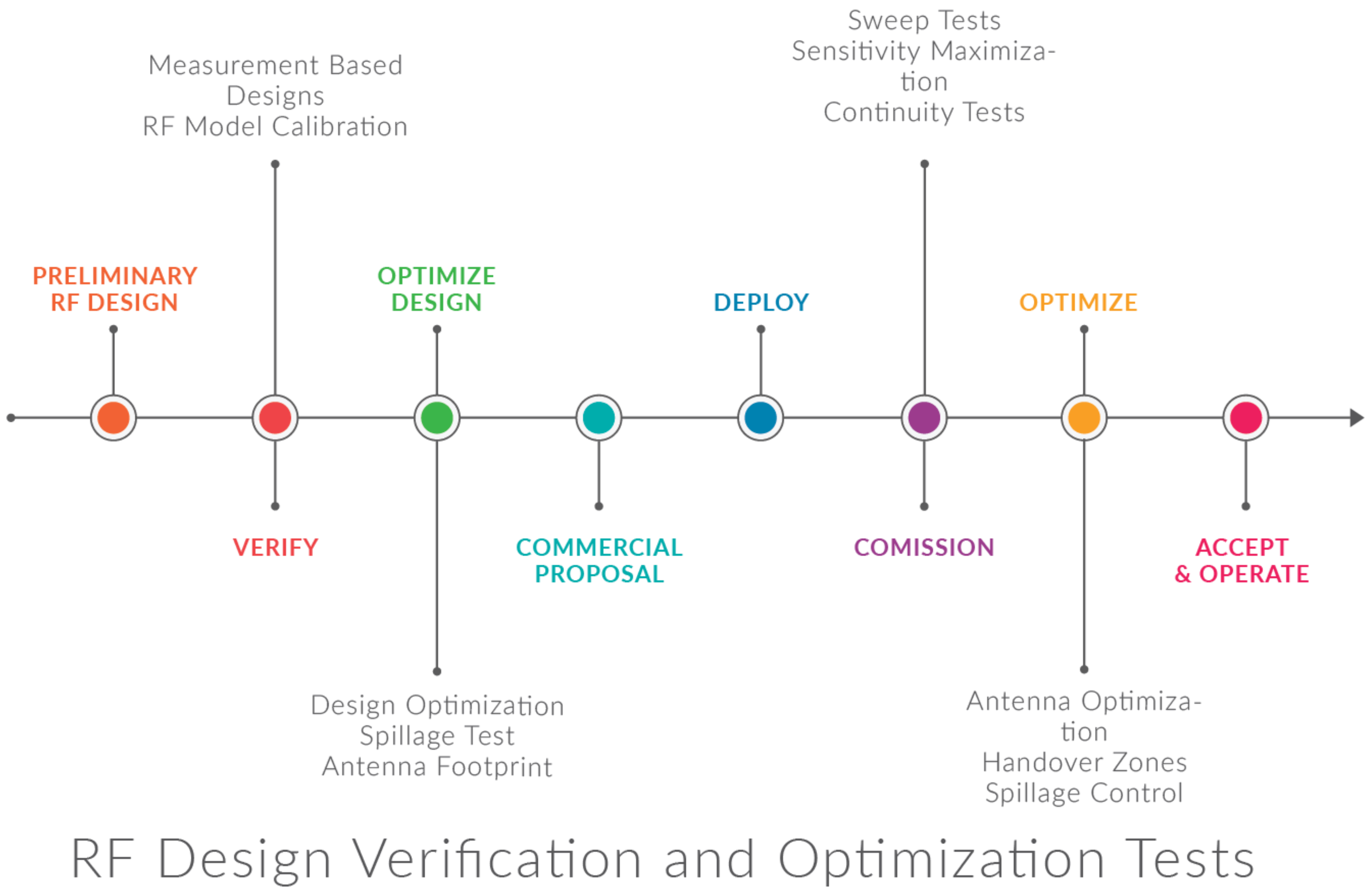


Figure 5 IBS testing timeline

CW Transmitter Walk-Testing

Used For:

- Actual Coverage heat maps for measurement-based-designs
- Propagation model calibration
- Wall losses calibration
- Overall coverage validation and comparison.

Tools Required:

- 1 x CW transmitter
- 1 x CW Receiver or Spectrum Analyzer
- Data recording/drawing software.

Procedure:

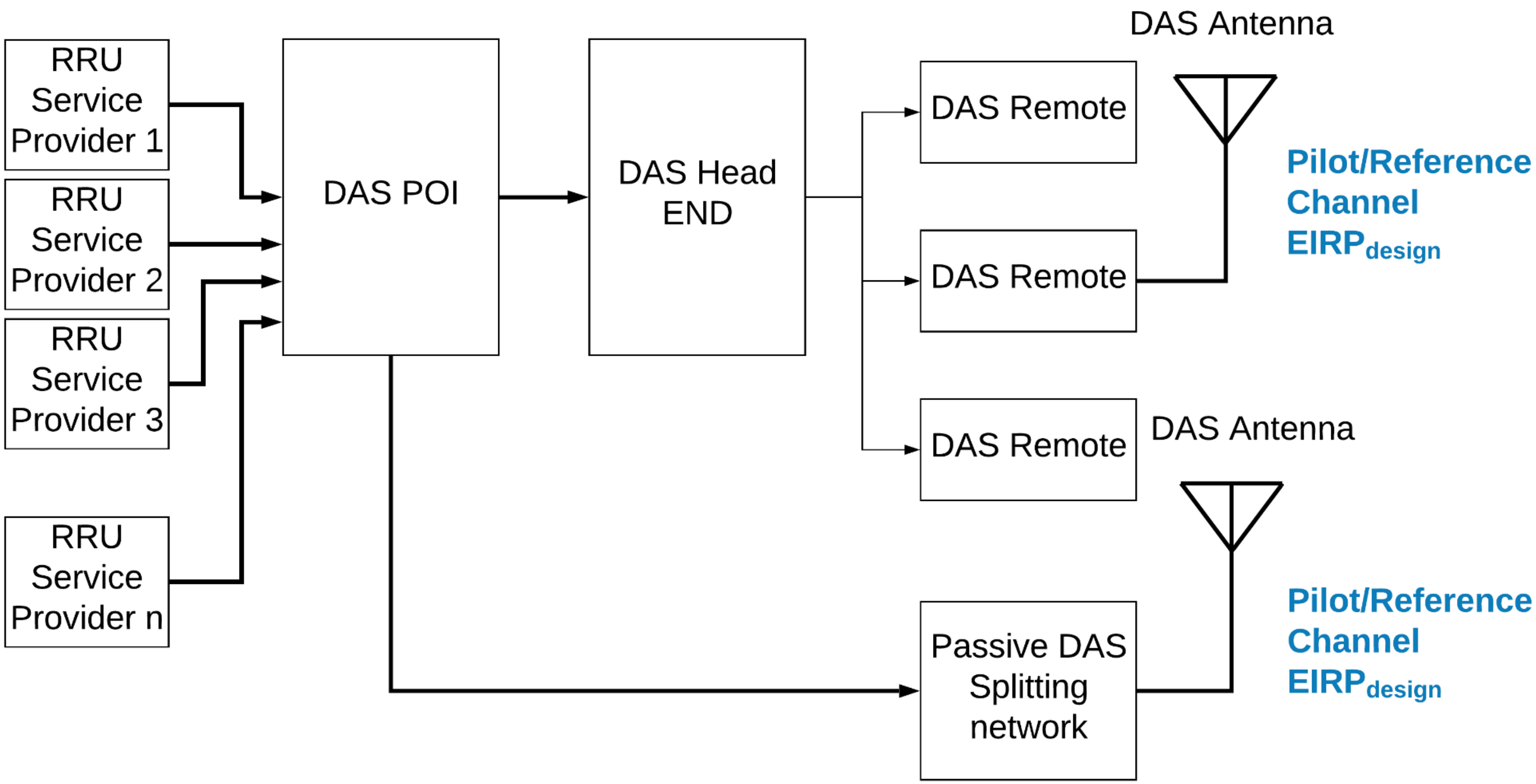
1. Setup and Measurement:
    a. Analyze different propagation environments of the building
    b. Identify required setups and testing routes
    c. Adjust the transmitter antenna height to appropriate levels
    d. Record All power settings, Jumper losses and Antenna model
    e. Perform walk testing with a receiver or spectrum analyzer.
2. Post processing
    a. Export data into simulation tools
    b. Perform model calibration as per your SW tool instructions.
    c. Alternatively, export Walk-test heatmaps on floor layouts for visual results and comparison with predictions.

Details

When performing CW testing for design verification, designers can have multiple options depending on the way they intend to use the test results:

1. For Measurement Based Designs and overall verification (Figure 6)
    a. Preliminary Design should be done prior to CW to know the output EIRP of the design
    b. To setup and perform CW with similar EIRP.
    c. To plot and compare to predictions
2. For Calibrating Propagation parameters (Figure 8)
    a. Designer is free to choose the output power of the Antenna during the CW test
    b. Propagation model parameters can be calculated using these values and the distance
    c. Import to the prediction software and follow its calibration procedures.

Preliminary RF Design Phase: Identify requied antenna locations and Expected RF Power



when comparing to real measurements: CW P_{Tx} should be set to match $EIRP_{design}$ of the Pilot signal

Figure 6 CW output power planning based on Design

Coverage verification : CW testing phase:

Target is to:

1. **Plot individual antenna coverage using designed values**
2. **Visually compare to designed values.**
3. **Alternatively, base RF design on CW plots**

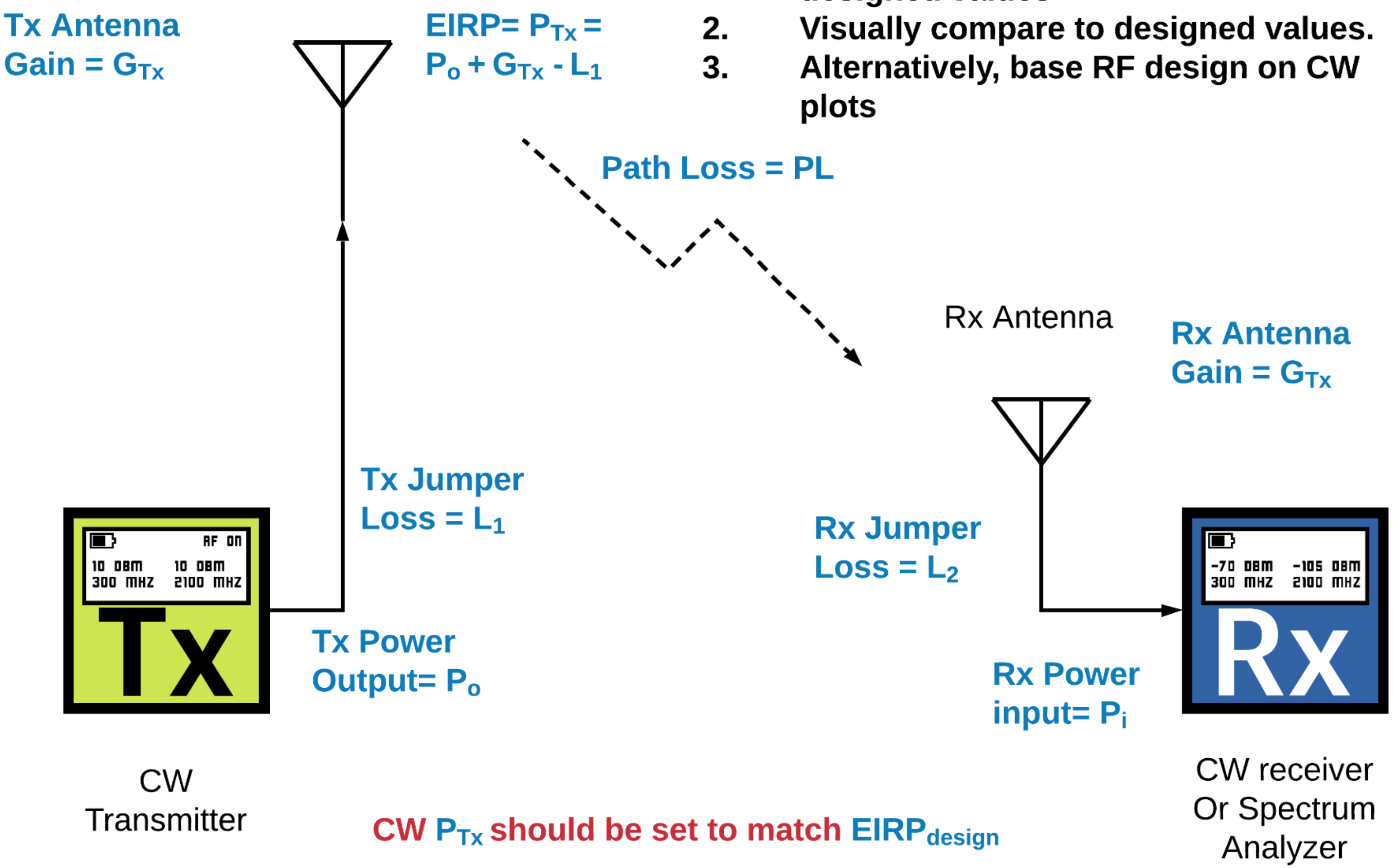


Figure 7 CW for Coverage verification

CW testing phase:

Target is to:

1. **Measure and plot Path loss PL**
2. **Calculating path loss exponent n PL**
3. **Alternatively, Import result into design tool for model calibration**

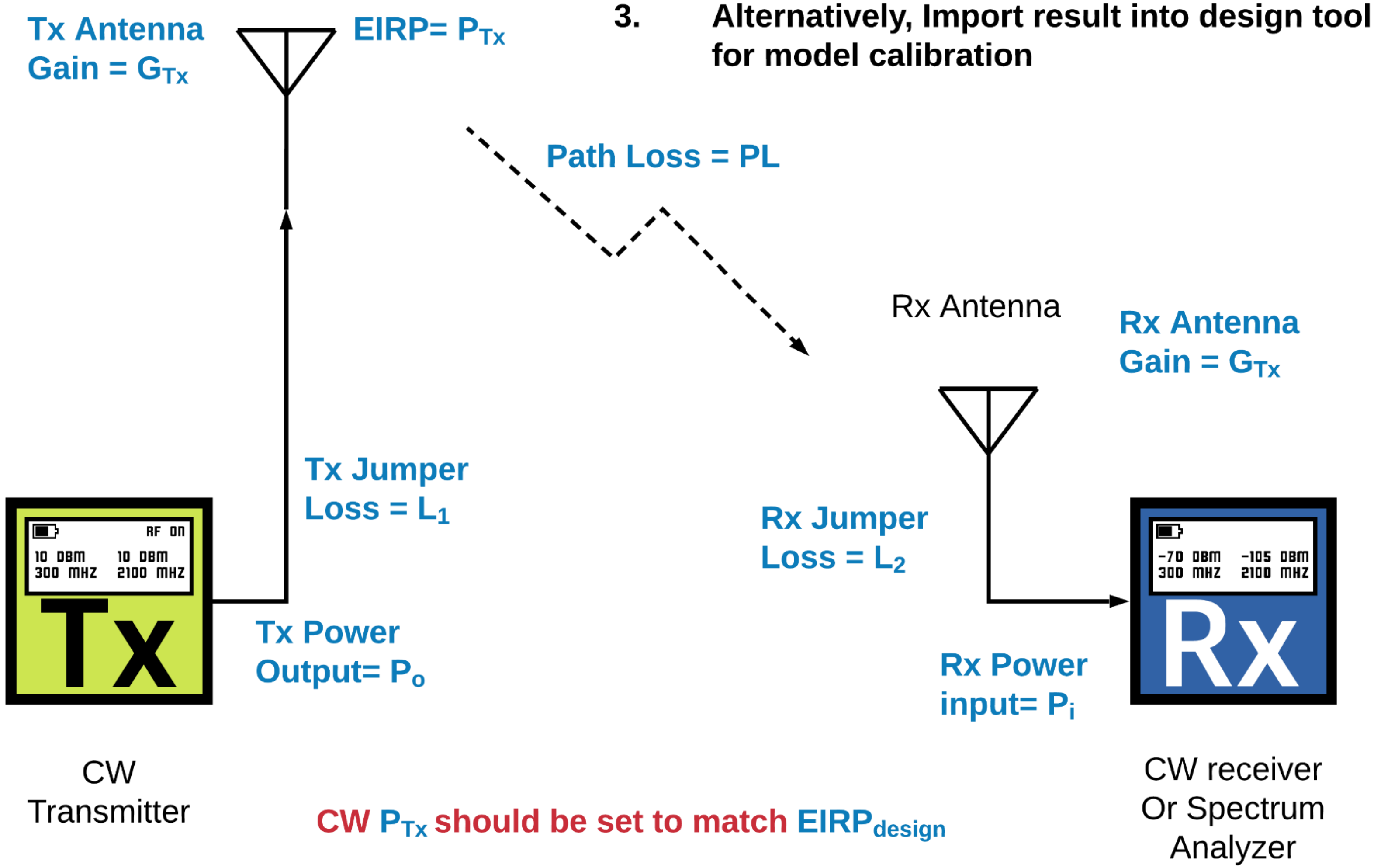
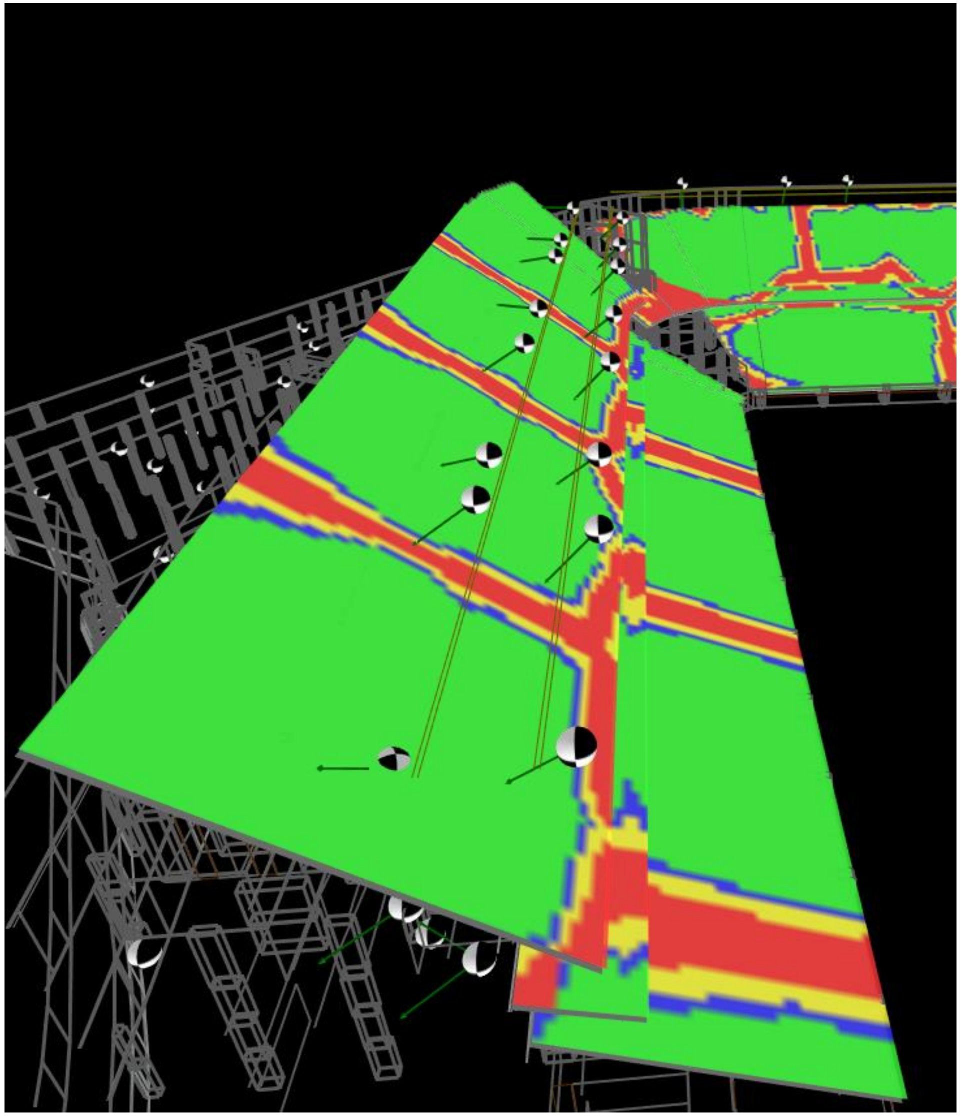


Figure 8 CW for model calibration

Antenna Coverage and Overlap



Used For:

Optimizing the Design either before or after implementation to gain more information on:

- Handover zones
- Sector Overlap

Important for stadiums and open propagation areas where sector overlap is required to be minimized.

Procedure:

Single antenna foot print requires a single transmitter.

Handover zones require two test transmitters or a multi-port transmitter (depending on the antenna separation).

Two different CW frequencies are injected into adjacent sectors' antennas.

Walk test recording and plotting of both signals to be compared and post processed for handover zone calculations.

The area to be scanned by the walk-test depends on the Application. And this is expected to be larger for measurement-based designs

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