International Telecommunication Union

ITU-R

Radiocommunication Sector of ITU

Recommendation ITU-R SM.2097-0

(08/2016)

On-site accuracy measurements of a fixed DF system

SM Series

Spectrum management

International Telecommunication Union

Foreword

The role of the Radiocommunication Sector is to ensure the rational, equitable, efficient and economical use of the radio-frequency spectrum by all radiocommunication services, including satellite services, and carry out studies without limit of frequency range on the basis of which Recommendations are adopted.

The regulatory and policy functions of the Radiocommunication Sector are performed by World and Regional Radiocommunication Conferences and Radiocommunication Assemblies supported by Study Groups.

Policy on Intellectual Property Right (IPR)

ITU-R policy on IPR is described in the Common Patent Policy for ITU-T/ITU-R/ISO/IEC referenced in Annex 1 of Resolution ITU-R 1. Forms to be used for the submission of patent statements and licensing declarations by patent holders are available from http://www.itu.int/ITU-R/go/patents/en where the Guidelines for Implementation of the Common Patent Policy for ITU-T/ITU-R/ISO/IEC and the ITU-R patent information database can also be found.

Series of ITU-R Recommendations

(Also available online at http://www.itu.int/publ/R-REC/en)

Series	Title
BO	Satellite delivery
BR	Recording for production, archival and play-out; film for television
BS	Broadcasting service (sound)
BT	Broadcasting service (television)
F	Fixed service
M	Mobile, radiodetermination, amateur and related satellite services
P	Radiowave propagation
RA	Radio astronomy
RS	Remote sensing systems
S	Fixed-satellite service
SA	Space applications and meteorology
SF	Frequency sharing and coordination between fixed-satellite and fixed service systems
SM	**Spectrum management**
SNG	Satellite news gathering
TF	Time signals and frequency standards emissions
V	Vocabulary and related subjects

Note: *This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.*

Electronic Publication
Geneva, 2016

RECOMMENDATION ITU-R SM.2097-0

On-site accuracy measurements of a fixed DF system

(2016)

Scope

This Recommendation provides guidance on standard methods of testing the bearing accuracy of a fixed direction finder in its final environment and reporting results. It may serve as part of a site acceptance test for monitoring services after the installation on site.

Keywords

Direction finder accuracy, on-site measurement, realistic environment

Related ITU Recommendations, Reports

Recommendation ITU-R SM.2060

Report ITU-R SM.2125

NOTE – In every case the latest edition of the Recommendation/Reports in force should be used.

The ITU Radiocommunication Assembly,

considering

a) that ITU-R has published the typical specifications for direction finding (DF) accuracy[1] in the ITU Handbook on Spectrum Monitoring (Edition 2011);

b) that the ITU Handbook on Spectrum Monitoring (Edition 2011) refers to Report ITU-R SM.2125 – Parameters of and measurement procedures on H/V/UHF monitoring receivers and stations, which defines the DF accuracy and provides some relevant test procedures;

c) that the specification of DF accuracy strongly depends on the test procedures applied;

d) that performance data in specifications of DF equipment usually reflects ideal test conditions and does not include the influences of obstructions, reflections and disturbing RF signals at the final installation site;

e) that the accuracy of a DF system on site may be strongly influenced by these environmental conditions[2] as well as the nature of the signal (signal strength, signal modulation including phase and time variant signals, signal duty cycle, signal polarization and signal duration), and the integration time of the DF;

f) that, depending on task requirements, one or more of these specific conditions may be more or less important, and in some cases, can be omitted;

---

[1] For purposes of the discussion in this Recommendation, "DF accuracy" is considered being the accuracy of a DF system's bearings to signals coming in from the horizon, with no consideration of signals arriving at other elevation angles such as skywave.

[2] In actual operating environments, multipath conditions can be simple or complex; they may be static or time-varying, and they will be different for different surrounding environments. These conditions will also change for different DF antenna heights at the same location.

g) that the site and installation of the DF system may directly impact its accuracy and suitability to fulfil certain monitoring tasks,

recommends

that the test procedures in Annex 1 should be used to determine and report the set of DF accuracies of a DF system installed at its final site.

Annex 1

1 Introduction

This Recommendation proposes general test procedures that can be used to evaluate the DF accuracy of a radio direction-finding system in its realistic RF environment. While the DF accuracy indicated by a manufacturer in the data sheet is a measure of performance under clean, controlled receiving conditions (as described in Recommendation ITU-R SM.2060), the tests described in this Recommendation are intended to evaluate the DF accuracy in the RF environment in which that particular DF system is installed. This environment is expected to include influences from the surrounding buildings, obstructions, reflections from nearby and moving objects and, in some cases, the presence of strong RF signals.

Performance measurements in clean, controlled environments give good results for DF accuracy comparisons. However, if the system does not perform adequately in an operational environment, its utility is degraded. Therefore, it is recommended to apply well-defined test procedures for fixed site installations for DF accuracy analysis in real operational environments, especially as a component of the acceptance tests of a system.

It is obvious that the DF accuracy, when measured in the actual operational environment, may be worse than the value stated in the data sheet, which is due to the usually negative effects of the operational RF environment. However, whether the DF errors measured on site may be (partly) compensated for (e.g. correction tables) depends on the system design.

It should be noted that the DF accuracy results measured with the methods described in this Recommendation are unique to the specific DF installation and cannot simply be transferred to other DF systems, even of the same type, in different RF environments.

It should also be noted that this procedure is not intended to be a complete site acceptance test. Though it may form the basis of a site acceptance test, there are usually more detailed requirements specified by the user based on their coverage and performance goals.

Two tests are recommended: (1) Tests using a test transmitter whose frequency and location can be controlled and which will transmit CW signals at a level that is adjusted to provide an SNR of 20 dB or more at the system under test, and (2) Tests using signals from existing known broadcast stations and other transmitters with known, fixed locations (termed “targets of opportunity”) which may be of varying modulation types and signal levels, with the provision that only signals from targets of opportunity will be used that have an SNR of at least the minimum value specified by the manufacturer of the system under test.

2 Measurement setup

The DF system should be tested in operational conditions at the actual location where the system will be used by the procuring administration. "Factory operational tests" may be an acceptable alternative, but should be done under conditions that are as close as possible to the expected conditions where the system will be deployed.

Determination of the coverage area for test

Prior to the DF accuracy tests, an analysis should be completed to determine the coverage area from test transmitters to be deployed, and from known broadcast stations and other transmitters with known locations (termed "targets of opportunity"). A suitable target of opportunity must have stable output power, and be capable of providing sufficient SNR for the duration of the test. Simulation tools can be used to analyse coverage based on the required transmitter power, frequency, modulation and location. This analysis will aid in planning the test transmitter locations and selecting targets of opportunity.

Test transmitter output power considerations

For controlled test transmitters, a CW signal should be transmitted at sufficient power to provide a received SNR of 20 dB or more, but by mutual agreement between the administration and the manufacturer, signals with the minimum SNR at which specified accuracy is achieved (as documented by the manufacturer) may be used. For targets of opportunity, the transmitted modulation types and signal levels will necessarily be used, but signals with a received SNR that is less than the minimum specified by the manufacturer will not be used.

Test transmitter and antenna considerations

Test equipment should be prepared for the field evaluation/testing. This equipment includes transmitters to generate signals over the frequency range of interest and with power appropriate to achieve the desired received SNR. The test equipment (including transmitter, transmitting antennas, etc.) should be calibrated to ensure valid data.

To most accurately simulate operational conditions, it is recommended that omnidirectional antennas be used with the transmitters. However, if mutually agreed, a directional antenna may be used for tests with a specific objective. These cases should be noted in the test results.

Test transmitter locations

Test equipment should be placed in a vehicle with a global positioning system and with appropriate power source (the test vehicle); the vehicle will drive to locations along roads in the calculated coverage area, to obtain at least eight well-distributed azimuth values within 360 degrees (two per quadrant).[3] The test points should have line of sight to the DF. The difference between any two adjacent test angles should be no less than 30 degrees. Where it is not practical to have this distribution of transmitter locations, other distributions are allowed, preferably keeping to a two-point-per-quadrant distribution, as long as the area of interest is covered.

A minimum of 8 test points should be used. The 8 test points should be at different distances from the DF system location ranging from close-in to the outer limit of the range of coverage. The test point with the longest distance should be at the limit of coverage to maintain a 20 dB SNR. For the short distance test point, it is sufficient to only be in the far field. The test points may be selected by administrations. Also, by mutual agreement between the manufacturer and administration,

[3] This would be the optimum situation for a DF system which covers 360 degrees. There may be reasons to modify this in cases where the DF is intended to cover fewer quadrants.

additional test points may be used, so that the administrations get a better understanding of the performance of the system in their environment.

Test transmitter frequency selection

The selected frequencies should be well distributed within the frequency range. However, they should be adequately separated (in frequency) from those of the "targets of opportunity" identified above so that the bearing result for the test transmitter signal is not influenced by the signal of an adjacent target of opportunity[4]. The methodology used for selecting test frequencies can follow Recommendation ITU-R SM.2060 (The final number of test frequencies may be limited by license restrictions or other factors).

Test transmitter modulation settings

The test should be performed with unmodulated (CW) carriers using the test transmitters as well as targets of opportunity as noted earlier. Targets of opportunity should include analogue and digital signals with modulation types typical of the signals to be received by the installed DF system, and typical of the operational environment.[5]

If the test is being performed with unmodulated carriers, the DF bandwidth should be set to a value in line with Recommendation ITU-R SM.2060. If the test is performed using a signal with analogue or digital modulation, the DF bandwidth should be adjusted according to the signal bandwidth.

Reporting of the test settings

All the test settings (test signal level in µV/m, test signal type, DF bandwidth, test point angle, test distance, antenna types, etc.) should be noted in the report.

3 Measurement procedure

The test vehicle should be driven to the first location. The global positioning system should be used to determine precise location, from which the true bearing from the DF system to the test transmitter is calculated. The test transmitter azimuth relative to the DF station (true azimuth) should be established with an accuracy of at least 0.1º RMS or a tenth of the estimated DF accuracy, whichever alternative is more restrictive, considering a confidence level of 95%.

The signal level of the test transmitter should be adjusted to make sure the field strength of the transmitted signal, as received at the DF antenna, has an SNR of 20 dB or more, unless it has been agreed between the administration and manufacturer to test at an SNR equivalent to the minimum signal strength advertised by the manufacturer at which specified accuracy is achieved. In addition, before switching on the test transmitter, it has to be verified that the selected frequency is "free" which means that no other signal is being received at the DF site.

Then the azimuth reading of the DF system is noted and entered into the data tables. The test should be repeated for the different frequencies. After all measurements at one location have been

4 In practice, this may be difficult to achieve with certain signals or certain modulation types, where multiple signals occupying the same frequency range may be present. Care should be taken to avoid these situations or some exception note may be needed.

5 By mutual agreement between administrations and manufacturers, testing of certain types of modulated signals may be specified.

completed, the Test Vehicle should move to the next location, and the measurement procedure repeated. This procedure is repeated until measurements have been made at all required azimuths[6].

In addition to the measurements of the test transmitter, the indicated bearings on the selected "targets of opportunity" are performed and the results are entered in the table, together with the calculated true bearings. For target of opportunity tests, the received SNR and the signal modulation are entered in the table.

Table 1 is an example of such a result table; one table is used for unmodulated (CW) signals and a similar table with additional columns for SNR and signal modulation is used for targets of opportunity.

TABLE 1

Sample test data table

Signal modulation ________________Signal polarization ________

	True	**Frequency 1**		**Frequency 2**		**Frequency 3**		**Frequency 4**			**Frequency M**	
Index	**Azimuth**	**DF**	**Δ**	**DF**	**Δ**	**DF**	**Δ**	**DF**	**Δ**		**DF**	**Δ**
1	1°											
2	28°											
3	77°											
8	354°											

Note that Δ is the bearing error for each measurement. It is calculated as the difference between the true azimuth and the displayed bearing on the DF equipment.

4 Test data analysis

If the measurements were done at the actual operating site as part of an acceptance test, the individual values in the result table are required. They may serve as a starting point for the user to create more comprehensive correction tables enabling some compensation of the bearing error at a later time.[7]

If the measurements were done as "factory operational tests", individual DF measurements may be averaged to produce a composite DF result for each case of azimuth, frequency and, if applicable, modulation, discarding at most 10% of the individual DF measurements as statistical outliers ("wild data").

The effective or RMS (root mean square) value of the bearing error, Δ_{RMS} for each frequency range, is calculated from averaged samples (after excluding outliers) using the formula:

---

[6] This kind of repeated testing can be efficiently conducted using software to control the transmitter and DF system, and collect and report the results.

[7] Additional angles and frequencies would need to be tested to create reasonable correction tables for an installed system.

$$\Delta_{RMS} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\Delta_i^2}$$

where:

N: count of measurement.

To ensure the reliability of results, the following requirements should be observed:

a) Up to 10% of the measurement samples made across the DF range in the coverage area (azimuth angles) may be discarded to account for operational problems, provided that a suitable process or procedure is developed for discard of such data.

b) The declared accuracy of the DF system should be the computed RMS of all data points other than those discarded. Discarded data should still be listed in the test report.

5 Additional considerations for HF DF measurements

The measurement of HF DF accuracy faces some further constraints:

– HF signal wavelengths require significant physical distances between transmitters and receivers, but the distance between test transmitter and DF system needs to meet the conditions of the far field;

– the level of atmospheric noise is not controllable (depends on the solar activity, daytime or nighttime, and other variables). It is often significantly higher than the DF system noise so that meeting the requirement of a minimum SNR of 20 dB may be difficult to ensure.

Measurements of HF DF accuracy should generally be the same as for VHF/UHF DF accuracy, except that:

– the transmitter could be a real broadcast transmitter with known characteristics (azimuth, level);

– an HF transmitter in a vehicle at a known position in a far field distance;

– the number of azimuths tested may be limited by geography or other factors;

– the type of tests described here consider only ground wave DF accuracy for HF direction finding systems, and other types of testing would be needed to evaluate skywave signals.

6 Example test results

The test results should be presented based on the physical frequency range of the DF antennas respectively, and for the targets of opportunity, the modulation type of the test signal, the DF bandwidth and other settings.

Considering a DF system operating with two sets of antennas, one could define the following test points as a minimum test consistent with this standard:

a) Antenna in the range of 80 MHz to 1 300 MHz.

  – 8 azimuth points, well distributed within 360º.

  – 13 frequency points, 2 points on the first decade of the operational range (80 MHz and 90 MHz), 9 points on the second decade (from 100 MHz to 900 MHz) plus 2 points to complete the range on the third decade (1 000 MHz and 1 300 MHz).

  – $N_t = 8 \times 13 = 104$ tests for each unmodulated carrier

  – N_0 = number of tests actually performed on analogue and digital modulations from targets of opportunity.

– Total $N = N_t + N_0$

b) Antenna in the range of 1 300 MHz to 3 000 MHz.

– 8 azimuth points, well distributed within 360º.

– 5 frequency points as the minimum since the range does not comprise full logarithmic decade (1 300, 1 640, 1 980, 2 320, 2 660, 3 000 MHz).

– $N_t = 8 \times 5 = 40$ tests for each unmodulated carrier.

– N_0 = number of tests actually performed on analogue and digital modulations from targets of opportunity.

– Total $N = N_t + N_0$

The Report based on operational test data could then read:

– DF accuracy: ≤ 2.5° RMS (80 MHz to 1 300 MHz, measured according to Recommendation ITU-R SM.2097-0);

– DF accuracy: ≤ 2.0° RMS (1 300 MHz to 3 000 MHz, measured according to Recommendation ITU-R SM.SM.2097-0).