INTERNATIONAL STANDARD

ISO 19926-1

First edition
2019-02

Meteorology — Weather radar —

Part 1:
System performance and operation

Météorologie — Radars météorologiques —

Partie 1: Performance et fonctionnement des systèmes

Reference number
ISO 19926-1:2019(E)

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Fax: +41 22 749 09 47
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 146, *Air quality*, Subcommittee SC 5, *Meteorology*, and by the World Meteorological Organization (WMO) as a common ISO/WMO Standard under the Agreement on Working Arrangements signed between the WMO and ISO in 2008.

A list of all parts in the ISO 19926 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The rapid development of weather radar occurred just before and during the Second World War. Initially, radar was demonstrated at long (10 m to 50 m) wavelengths, but quickly moved to shorter wavelengths (3 cm and 10 cm) with the requirement for, and development of, compact and high-power transmitters. C-band (5 cm) wavelengths were available in the late 1950s. The first operational Doppler radars appeared in the mid-1980s, with demonstration of the technology's application in operations and the availability of high-speed, affordable processors and efficient software codes. The adoption of dual-polarization capability for operational radars followed in the mid to late 1990s.

Radars provide localized, highly detailed, timely and three-dimensional sensing and observing capability that no other meteorological monitoring system can provide. They are able to measure variations in precipitation rates at a resolution of a few square kilometres or better and at time cycles of the order of a few minutes. They provide the capability to monitor rapidly evolving weather events, which is critical for the provision of early warnings of severe and hazardous weather. This includes heavy rain, hail, strong winds (e.g. tornadoes and tropical cyclones) and wind shear; the conditions that have the highest impact on society of all the weather elements. Doppler and dual-polarization radars are able to resolve the high variability of wind and precipitation types, and even see insects or clear air turbulence used to predict the onset of thunderstorms and for measuring vertical wind profiles. Dual polarization is also used for quality assurance and to improve precipitation estimates.

With high speed telecommunications and data processing, radar systems are now networked to better monitor large-scale weather phenomena, such as tropical cyclones and major extra-tropical storms (both in summer and winter). The data derived from the networking of radars can provide longer lead times (from 60 min to 90 min to several hours) for early warnings. Numerical weather prediction systems have also now advanced and the assimilation of continental-scale radar-derived precipitation data into global models can significantly improve the 4-day to 5-day precipitation forecasts of neighbouring areas and continents.

The provision of homogeneous, high-quality data starts with the installation and use of appropriate radar technology for the local weather environment and conditions. The wavelength of the radar, the beam width of the antenna, the type and power of the transmitter, the sensitivity of the receiver and the waveform all have significant impacts on the resolution and quality of radar data. Weather radars have traditionally been specified and configured to meet local requirements for weather monitoring and surveillance and to cater for local geography and other factors, leading to globally diversity in technology and in sampling strategies. These all impact on different data quality metrics, such as availability, timeliness and accuracy. These metrics also rely on the operation and maintenance of the radar systems through adherence to prescribed and standardized procedures and practices. This requires the establishment of standards, technical specification best practices and guidelines for network design, site selection, calibration, system and equipment maintenance, sampling and data processing, and distribution.

The purpose of this document is wide and addresses organizations in all countries using weather radar, with particular emphasis on countries that do not have a long tradition of weather radar operation and usage. It provides:

— support to manufacturers to maintain a comparable and high level of competitive weather radar systems;

— aid for tendering authorities to take into account state of the art of system performance as well as merely component definitions in their documents and, thus, to help to compare different incoming bids;

— provision of a valid documentation on the potential and limitations of weather radar systems, thus supporting capacity building worldwide;

— advice on the general requirements for siting, operation, maintenance and calibration tasks to keep radar systems on a high level of data quality and availability;

— a description of the required range of tasks for operating and maintaining weather radar systems in order to let managers allocate enough financial resources and staff capacity for this purpose.

Further information, such as the fundamentals of weather radar measurement, can be found in Reference [1].

Meteorology — Weather radar —

Part 1:
System performance and operation

1 Scope

This document specifies system performance of ground-based weather radar systems measuring the atmosphere using frequencies between 2 GHz and 10 GHz. These systems are suitable for the area-wide detection of precipitation and other meteorological targets at different altitudes. This document also describes ways to verify the different aspects of system performance, including infrastructure.

This document is applicable to linear polarization parabolic radar systems, dual-polarization and single-polarization radars. It does not apply to fan-beam radars [narrow in azimuth (AZ) and broad in elevation (EL)], including marine and aeronautical surveillance radars, which are used for, but are not primarily designed for, weather applications. Phased-array radars with electronically formed and steered beams, including multi-beam, with non-circular off-bore sight patterns, are new and insufficient performance information is available.

This document does not describe weather radar technology and its applications. Weather radar systems can be used for applications such as quantitative precipitation estimation (QPE), the classification of hydrometeors (e.g. hail), the estimation of wind speeds and the detection and surveillance of severe meteorological phenomena (e.g. microburst, tornado). Some of these applications have particular requirements for the positioning of the radar system or need specific measurement strategies. However, the procedures for calibration and maintenance described in this document apply here as well.

This document addresses manufacturers and radar operators.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

4 Abbreviated terms

ADC analogue–digital converter

AZ azimuth

BITE built-in test equipment

BPF band-pass filter

CW	continuous wave
EL	elevation
H/V	horizontal/vertical
HPBW	half power beam width
ITU-R	International Telecommunication Union, Radiocommunication Sector
LDR	linear depolarization ratio
LNA	low noise amplifier
MTBF	mean time between failures
NF	number of failures
NMHS	National Meteorological and Hydrological Service
PRT	pulse repetition time
QPE	quantitative precipitation estimation
RF	radio frequency
SG	signal generator
SNR	signal-to-noise-ratio
STALO	stable local oscillator
STAR	simultaneous transmit and receive
TR	transmit/receive
TWT	travelling wave tube
UPS	uninterrupted power supply

5 Basics

5.1 Frequency bands

A weather radar is a system that is designed to measure hydrometeors in a large area, using a remote-sensing technology based on microwaves. The microwaves of S-, C- and X-bands are used in many cases and the scale and observation characteristics of the system are different depending on the characteristics of each frequency (wavelength). S-band systems are large and their observation range is wide, while X-band systems are compact and their observation range is narrow. The useful range of S-band and C-band radars are typically limited by the Earth's curvature (≥ 300 km), whereas at X-band the limit is normally attenuation dependent (50 km to 100 km). See Reference [1] for more details. Table 1 shows the typical items for each frequency band.

It is necessary to select the frequency band according to the range of observation and the scale of system at the location.

Table 1 — Typical specification for different frequency bands of weather radar

Frequency band	Frequency range[a]	Antenna diameter[b,c]	Rain attenuation (two-way) at 30 mm/h[d]
S	2,700 GHz to 3,000 GHz	8,5 m	0,02 dB/km
C	5,250 GHz to 5,900 GHz	4,2 m	0,13 dB/km
X	9,300 GHz to 9,800 GHz	2,4 m	1,22 dB/km

[a] Operating frequency range differs from each country.

[b] For more information on frequency band and antenna size, refer to Reference [1], Chapter 7.6.8.

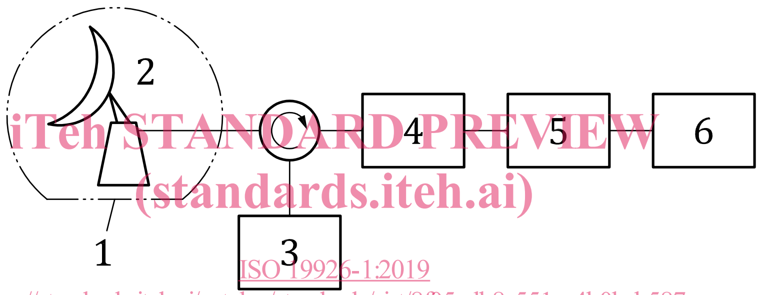
[c] Typical values for a 1° HPBW.

[d] For attenuation due to rain, refer to Reference [1], Chapter 7.2.3.

5.2 System configuration

5.2.1 Overview of radar system component units

Figure 1 shows the basic configuration of a radar system. Antenna mounted receivers (and in some cases transmitters) are also becoming common recently.

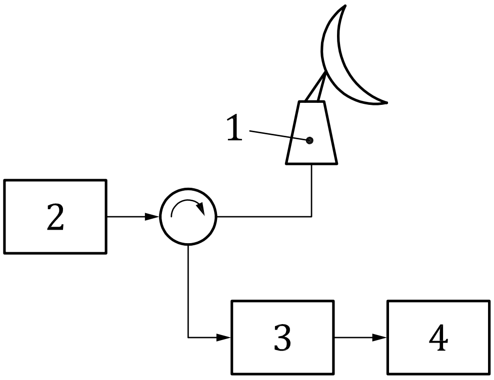


Key

1 radome
2 antenna
3 transmitter
4 receiver
5 signal processor
6 data processor

Figure 1 — Configuration and diagram of radar system

The weather radar system is divided into a single-polarization type, which is in most cases horizontal polarization (see Figure 2), and a dual-polarization type, where both horizontal and vertical polarizations of the emitted and received microwaves are used. The dual-polarization type is further divided into a dual-polarization distribution transmitter type (see Figures 3 and 4), which distributes single transmitter output, and a dual-polarization independent transmitter type, which has two independent systems of transmitter (see Figure 5).



Key

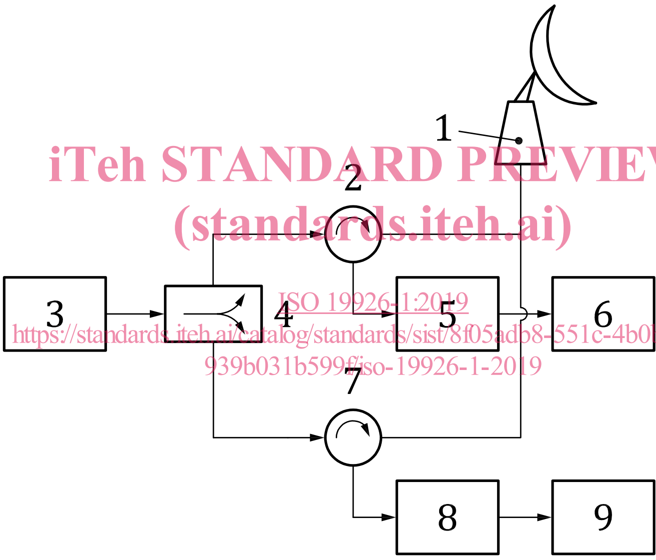
1 antenna

2 transmitter

4 TR limiter

5 receiver

Figure 2 — System diagram of a single-polarization type



Key

1 antenna

2 horizontal polarization (H) channel

3 transmitter

4 3 dB power splitter

5 TR limiter

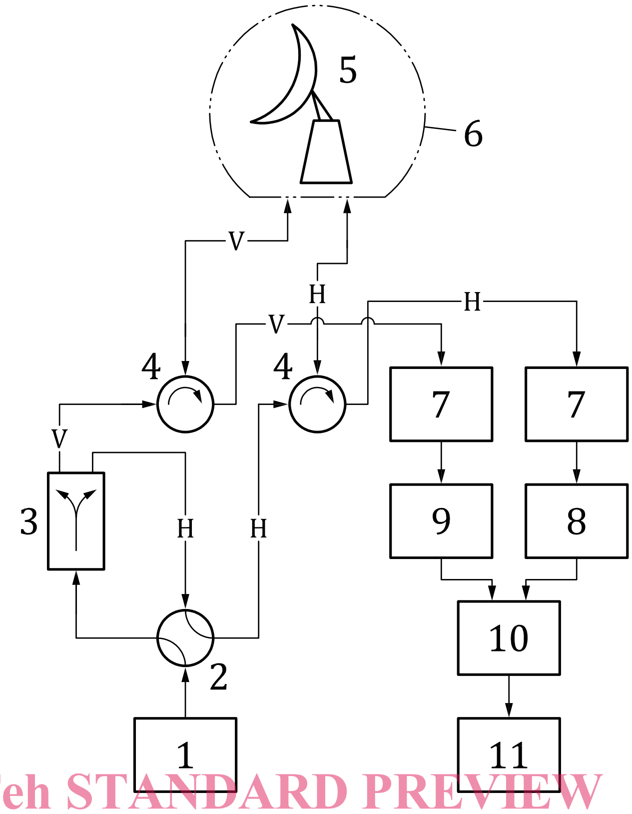
6 receiver (H channel)

7 vertical polarization (V) channel

8 TR limiter

9 receiver (V channel)

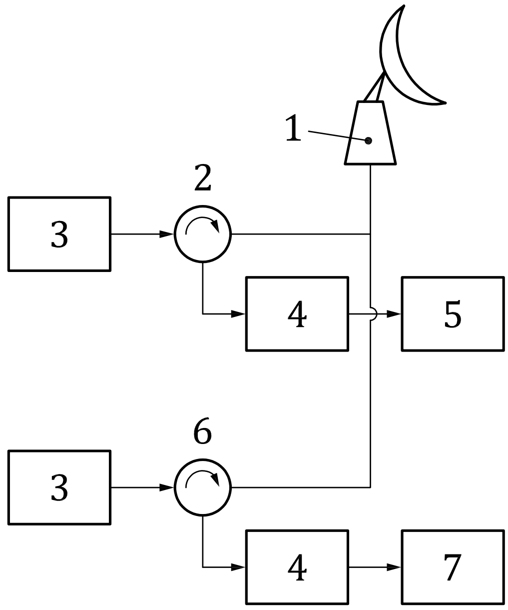
Figure 3 — System diagram of a dual-polarization distribution transmitter type



Key

1 transmitter
2 polarization mode switch
3 3 dB power splitter
4 circulator
5 antenna
6 radome
7 TR limiter
8 horizontal polarization receiver channel
9 vertical polarization receiver channel
10 signal processor
11 data processor

Figure 4 — System diagram of a dual-polarization distribution transmitter type plus additional linear depolarization ratio mode



Key

1 antenna

2 horizontal polarization (H) channel

3 transmitter

4 TR limiter

5 receiver (H channel)

6 vertical polarization (V) channel

7 receiver (V channel)

Figure 5 — System diagram of a dual-polarization independent transmitter type

5.2.2 Dual-polarization transmit modes

5.2.2.1 General

Depending on the transmitter system (see types dual-polarization distribution transmitter or independent transmitter illustrated above) different transmit modes are available.

5.2.2.2 Simultaneous transmit and receive or hybrid mode

In simultaneous transmit and receive (STAR) mode, a linear horizontal and a vertical polarized wave is transmitted simultaneously and each wave is received by the respective receiver chain. The advantages of this technique are that it can be used with a single transmitter (distributed transmitter type), no expensive second transmitter is required and a simple power splitter in the transmit path is sufficient. The disadvantage is that, in the case of a depolarizing medium (e.g. melting layer, wet or melting hail), a cross-talk between horizontal and vertical waves occurs and contamination of radar products (e.g. differential reflectivity Z_{dr}) will occur.

5.2.2.3 Alternate H/V mode

In the alternate H/V mode, horizontal and vertical polarized waves are transmitted alternatively from pulse to pulse. Two receivers will receive the co-polar and the cross-polar signal for each pulse. The advantage of the alternate H/V mode is that both the co-polar and cross-polar components of the scatter matrix can be measured. If the radar is of the distributed transmitter type, a polarization switch is required instead of the power splitter. Fast high-power switches are currently expensive and brittle. For that reason, the alternate H/V mode is normally only used for research radars, which are not operated continuously. In cases where the radar uses two independent transmitters, the alternate H/V mode can be simulated by transmitting alternately every second pulse per transmitter.

5.2.2.4 Linear depolarization ratio mode

The linear depolarization ratio (LDR) mode is a special mode enabling radars built in the distribution transmitter type configuration (see Figure 4) to measure the LDR. LDR is the ratio between cross-polar and co-polar reflectivities. LDR is a good indicator for melting layer or wet or melting hail and ground clutter. To enable LDR mode, a bypass around the power splitter is necessary. This bypass will send the transmit power only to the horizontal feed. On receipt, the horizontal polarization receiver measures the co-polar signal and the vertical polarization receiver measures the cross-polar signal. Typically, a slow switch (switching time approximately 1 s to 3 s) is used and the change between STAR and LDR modes will be performed after only one plan position indicator (PPI) scan. With the exception of LDR, no other dual-polarization product can be measured.

5.2.3 Description of components

5.2.3.1 Antenna

A directional antenna is used to concentrate energy into a narrow beam. A parabolic reflector type is generally used. The size of the antenna to obtain the same beam width is different depending on the frequency used. If the wavelength is shorter, the same beam width is realized by a parabolic antenna with a smaller diameter. Generally, a single antenna has the dual purpose of transmission and reception. In addition, the antenna is divided into a single-polarization type (one feed horn) and a dual-polarization type (a feed horn capable of separating two orthogonal polarizations).

Phased array antenna is an emerging technology for weather radars, where the antenna is a panel of several solid-state emitters. See Annex F for more details.

5.2.3.2 Radome

A radome is used to cover the antenna and to protect it from rain, wind, ice and snow. The radome is formed as a spherical or dome type by combining a multiple number of panels. The radome is of a variety of types depending on the size and the purpose of the observation of antenna.

The radome for dual polarization is devised to show a behaviour as uniform as possible for both horizontal and vertical polarized waves crossing the radome. This can be achieved by proper design of the panel shapes, for example, by using geodesic or quasi-random geometry of these panels.

The radome will introduce several losses. See A.3.9.2 for estimation of losses of a dry radome. It has to be noted that water, snow or ice on the radome can lead to strong losses (some dB).

5.2.3.3 Transmitter

5.2.3.3.1 General aspects

A transmitter is a device to generate transmission radio waves. It generates a stable high-power microwave pulse and radiates radio waves into the air via antenna. There are two types of transmission devices: electron tube [magnetron, klystron, travelling wave tube (TWT), etc.] and semiconductor (solid-state). For TWT and solid-state transmitters, the pulse-compression technology is applied to obtain fine resolution and to increase the signal-to-noise ratio (SNR).

In pulse-compression radars, a long and short pulse are usually transmitted alternately, since, while transmitting a long pulse, a blind range is generated and this needs to be covered. A long and short pulse transmission example is illustrated in Figure 6.