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this chapter begins with sect 1 on brief history of timekeeping and evolution of clocks the classification of atomic frequency standards is described in sect 2 along with description principle of operation and other significant details on each type of atomic frequency standards a rubidium standard or rubidium atomic clock is a frequency standard in which a specified hyperfine transition of electrons in rubidium 87 atoms is used to control the output frequency a frequency standard is a stable oscillator used for frequency calibration or reference a frequency standard generates a fundamental frequency with a high degree of accuracy and precision harmonics of this fundamental frequency are used to provide reference points the caesium standard is a primary frequency standard in which the photon absorption by transitions between the two hyperfine ground states of caesium 133 atoms is used to control the output frequency this review provides a snapshot and an outlook of commercial and emerging atomic frequency standards we provide a concise summary of the performance and physics of operation of current atomic frequency standards an atomic frequency standard is a frequency standard whose basic resonant system is an atom or molecule experiencing a transition between two quantized energy levels an atomic frequency standard provides a stable frequency output typically at 10 mhz atomic frequency standards on the technical and scientific user community introduction the last comprehensive survey of atomic frequency standards was done eight years ago by a 0 mccoubrey I since then consider able changes have taken place in the field companies who were manufacturing atomic stand the first practical cesium atomic frequency standard was built at the national physical laboratory in england in 1955 and in collaboration with the u s naval observatory usno the frequency of the cesium reference was established or measured relative to astronomical time the development of atomic frequency standards at nist is discussed and three of the key frequency standard technologies of the current era are described for each of these technologies the most recent nist implementation of the particular type of standard is described in greater detail nist builds and operates the country s most accurate atomic clocks which help set the global time scale known as coordinated universal time through its own time scale nist provides time to the nation and the world via the internet and radio published january 1 2001 author s donald sullivan james c bergquist robert e drullinger wayne m itano steven r jefferts d w lee d meekhof thomas e parker f l walls david j wineland citation journal of research of the national institute of standards and technology volume 106 pub type journals citation gnss grade space atomic frequency standards current status and ongoing developments we present an overview on the current state of global navigation satellite systems gnss grade or better space atomic frequency standards safs technologies and discuss their applications we estimate that a total of more than 1000 such standards were this survey reviews the more recent historical background of atomic frequency standards leading to the present developments a discussion of the underlying physical and engineering principles is given the relative precision obtainable with atomic frequency standards is unsurpassed in any field and the precision limitations in this field are largel due to inherent noise in the atomic device and the associated electronic equip ment a practical and straightforward method of determining the power spectral density of the frequency fluctuations from the variance of the frequency fluctuations the sampling time the number of samples taken and the dependence on system bandwidth is also developed the basic concepts involved in atomic frequency standards and the terminology commonly used in this field are summarized the role of quartz crystal oscillators which are slaved to active and passive atomic frequency standards is emphasized atomic frequency standards provide the most accurate measurements in physics the quantum physics of atomic frequency standards is an extensive

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