ESA TRACKING SYSTEMS

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ABSTRACT

This paper presents the tracking systems currently used at ESA. Two systems are described: Meteosat Ranging System (MRS), and Multi-Purpose Tracking System (MPTS).

The MRS is presently in operational use on Meteosat. It has been designed to meet the need for a simultaneous multi-point ranging in a channel shared with other services. As a result, a new code ranging technique, based on split-phase-level data formats, has been designed and developed.

The MPTS (previously Deep Space Tracking System - DSTS) was first developed and deployed for the Giotto mission. At a later stage, a near-earth capability has been added to the system, thereby creating a truly multi-purpose tracking system. The ranging signal employed in the MPTS makes use of the good properties of both the PN code type of ranging system and the tone ranging system.

The concept, architectural design, capabilities and performance of these systems are presented in this paper. Finally, insight into the European Data Relay Satellite and Data Relay User Satellite ranging systems is given.

1. INTRODUCTION

The Meteosat Ranging System (MRS), and the Multi-Purpose Tracking System (MPTS) are based on very different concepts for very different applications. Both systems however share the quality of providing accurate range data to the spacecraft orbit-determination process. Ranging a satellite is performed by measuring the round-trip delay of a signal between an Earth station and the satellite. There are various ways to generate a ranging signal but all of them are based on the modulation of a time marker onto the uplink that will be subsequently detected by the receiver on the downlink. Periodic time markers are employed in order to accommodate noisy transmission channels.

The MRS is an example of code ranging system. The code in this case serves the purpose of a time marker. Codes can be pseudo-random or patterns selected in order to fulfill specific requirements. The MRS code is a pseudo-random code, also called pseudo-noise code (pn-codes). It offers very good spectral properties and orthogonal codes can be chosen to enable multiple satellite access.

The MPTS is a hybrid tone-code ranging system. A pure-tone ranging signal consists of a high frequency ‘major tone’ that is continuously transmitted together with a set of sub-harmonically related ‘minor’ tones which are sequentially transmitted. The round-trip propagation time is given by the measured tone phase difference between the uplink and the downlink. The accuracy of the measurement is given by the highest tone frequency, in this case, the major tone. The set of minor tones serves the purpose of gradually resolving range ambiguity. The lowest frequency component defines the limit for range ambiguity resolution [4].

The MPTS code is essentially a binary representation of the minor tones, multiplied together: it consists of a series of sub-harmonically related digital codes of increasing length. The MPTS combines the advantages of both types of ranging systems: fast acquisition property that characterizes a pure-tone ranging system, with the good interference properties inherent in code systems.

Another feature of the MPTS is its combined Range-Doppler capability. It allows to acquire deep space ranging signals that are approximately 30 dB lower (-10 dBHz) than a conventional pure-tone ranging system can acquire. The MPTS measures the Doppler shift on the carrier to predict the tone frequency and pre-steer accordingly the tone PLL for tone acquisition. This technique is referred to as “Doppler pre-steered range-tone tracking loop” and is further described in section 3.

2. METEOSAT RANGING SYSTEM

The Meteosat Ranging System (MRS) was first designed and used for Meteosat, a series of meteorological satellites operated by ESA on behalf of Eumetsat under the “Meteosat Programme”. The Meteosat satellites observe cloud formation across the full Earth disk and generate various meteorological images and charts such as Weather Facsimile (Wefax) charts that are transmitted to the ESA ground station and finally to the end-users via Meteosat. These signals are referred to as “communication signals” as opposed to ranging signals. Both ranging and communication signals share the same satellite transponder as described in the next section.

CONCEPT

The system architecture and location have been chosen in order to meet the performance required on Meteosat, satellite located at around 0º longitude. The MRS is a two-terminal system: the primary ranging terminal located in the Data Acquisition Tracking and Telecommand Station (DATTS) in Odenwald, Germany, and the Land-Based Transponder (LBT) located in Kourou, French Guyana. Figure 1 illustrates the concept: ranging and communication signals are transmitted simultaneously from the primary station to the satellite and transponded both to the primary station as well as to the LBT. The LBT demodulates and retransmits coherently the ranging signal to the primary station via the satellite. 4-way (DATTS-satellite-LBT-satellite-DATTS) and 2-way (DATTS-satellite-DATTS) range data are provided by the primary station to the orbit-determination process carried out in the Operational Control Center (OCC), located in Darmstadt, Germany. Multiple satellite access among the ranging terminals is achieved by choosing orthogonal codes [1].

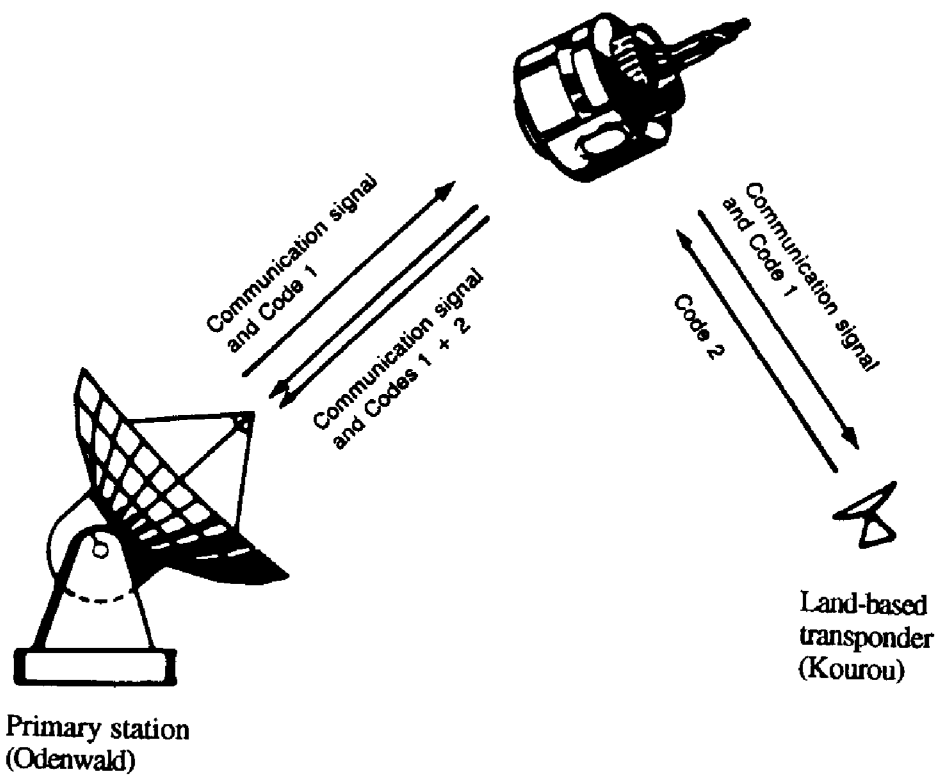

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Fig. 1: Meteosat multiple-access ranging concept

The ranging signal is a pn-code that is Split-Phase-Level (SPL) data formatted and directly phase modulated (BPSK) onto the carrier. It is transmitted at a very low signal level, approximately 20 dB below the communication signal. The SPL pulse shape offers the advantage of minimum spectral density around the carrier frequency, thereby minimizing the mutual interference between ranging and communication signals and enabling simultaneous access to the satellite [1]. The pn-code is also used as spreading code for a low rate data stream with bit-duration equal to the code length; this data stream is to transfer data and control between the primary station and the LBT.

CAPABILITIES

The MRS was designed as a ranging-only system. Doppler measurements are not required on Meteosat to meet the required performance.

Operational modes

The MRS ranges two types of transponders existing on Meteosat: the Mission Performance Telecommunications (MPT) transponder, and the Mission Support Telecommunications (MST) transponder. The MPT transponder is specifically used for operational satellites and is shared between user services and ranging in a CDMA fashion as described in the previous section. In this mode, 4-way and 2-way ranging are performed in order to meet the required accuracy. Hibernated or spare satellites are ranged via another transponder, the MST transponder, in a 2-way mode only, which provides sufficient accuracy. Unlike MPT, the MST transponder is not used for user services.

PERFORMANCE

An analysis of the ranging measurement accuracy and of the interference effects on the simultaneously transmitted communication signal is given in ref. [1]. Link budgets are given for MPT operations.

MRS ranging data and orbit predictions have been compared: the overall MRS performance, including noise performance, stability of the path through the station, the satellite, tropospheric and ionosheric propagation degradation has been measured to be 1.1 m in SPL under nominal link budget conditions.

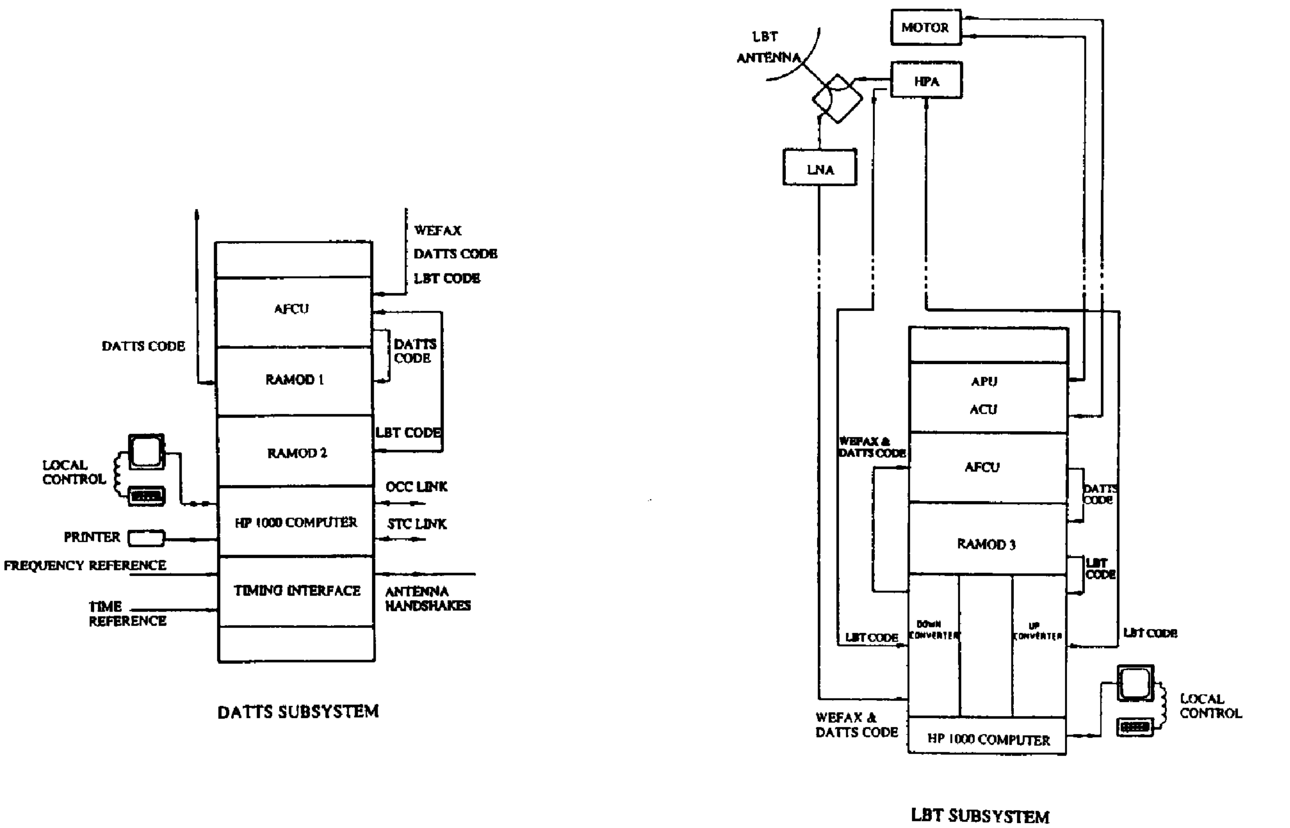
The ambiguity resolution is given by the code length. In the case of the MRS, it ranges from 0.1 sec to 0.025 sec (10 to 40 codes per second in SPL), resulting in a maximum non-ambiguous range of up to 15,000 km. This gives a sufficient ambiguity resolution for geostationary satellites. Moreover, a synchronization word is coded onto the unspreaded ranging signal every 2 sec, allowing further resolution of the range ambiguity.

A detailed performance analysis as well as link budget information is in ref.[1].

ARCHITECTURE

Ranging terminals

The MRS primary ranging terminal consists of two RAnging MODulator/Demodulators (Ramod 1, and Ramod 2), an Automatic Frequency Control Unit (AFCU), a Frequency and Timing Unit and a central real-time computer as shown in Fig 2. Ramod 1 and 2 are identical drawers, however only Ramod 1 is used in transmission mode. At the reception, the 2-way code, code 1, and the 4-way code, code 2, are demodulated by Ramod 1 and Ramod 2 respectively. In MST mode only Ramod 1 is used. The LBT architecture is very similar to the primary terminal, except that only one Ramod is implemented and RF and front-end equipment is included in addition to the ranging drawers (see fig. 2). Minor operational differences exist at the drawer level such as the LBT Ramod which operates nominally in a transponed mode, unlike the DATTS Ramods.



APU: Antenna Power Unit
ACU: Antenna Control Unit
HPA: High Power Amplifier
LNA: Low Noise Amplifier

Fig. 2: MRS block diagram

In MPT mode, the MRS architecture is based on the concept of simultaneous transmission of a ranging signal and a communication signal. The ranging acquisition technique used here, makes good use of the presence of a communication signal that is 20 dB stronger than ranging and that is centered around the same frequency as the ranging signal [1]. The acquisition follows a two-step process: first the AFCU acquires the user center frequency, and then delivers the ranging signal to both Ramod 1 and Ramod 2. Second, both Ramods resolve the code phase by means of a sliding correlator [1]. Start pulses and stop pulses, generated in synchronization with code transmission and code acquisition, are input into a Time Interval Counter which computes the time difference. Range ambiguity is further resolved by the MRS computer using the synchronization word modulated onto the ranging signal every 2 seconds. Further detailed hardware description is best given in [1] and [3].

Ground Station

Ranging requests are issued remotely by OCC. It can also be done locally from DATTS. Prior to each ranging, a DATTS configuration or at least a check on station configuration is carried out by the Station Computer (STC). A simplified block diagram of the primary ranging station is given in Fig 3. The MRS interfaces with the up- and downlink chains through an Up-Combiner Switching Unit (UCSU) and a Ranging Downlink Switching Unit (RDSU) that are controlled by the Station Computer (STC).

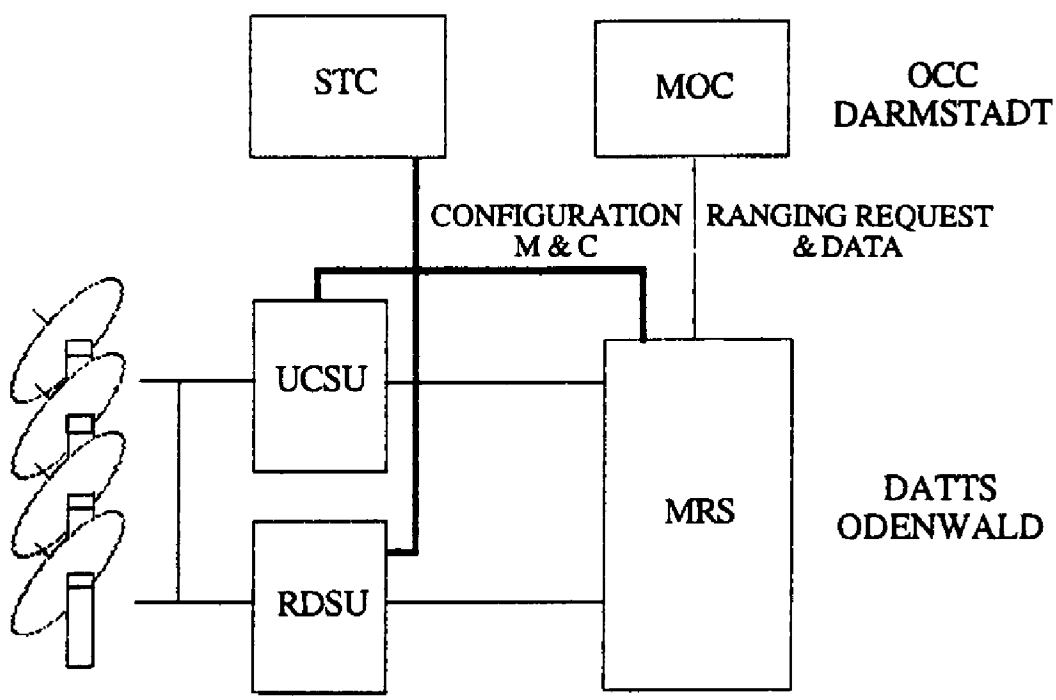


Fig. 3: MRS integration in the ODW DATTS station

MRS: PRESENT and FUTURE

The MRS was originally designed to range a single operational satellite in a 4-way mode using its primary station and its Land-based transponder, and to range hibernated satellites in a 2-way mode using the primary station only. Since then the requirements have evolved and the MRS capability has been enhanced in 1991. Today, ranging measurements of up to 4 satellites, either in 2 or 4-way mode, can be performed in an automatic fashion following a command schedule, thereby creating a truly multi-satellite ranging system (see fig.3). A detailed system specification is given in ref.[2].

Presently, a second MRS is under production which will provide support to NOAA, the National Oceanic and Atmospheric Agency. NOAA will purchase through ESA the ground segment, and lease one Meteosat until the NOAA satellite GOES is launched. The primary ranging terminal will be installed in a second DATTS, DATTS-2 called “Wallops Meteosat Ground Station” (WAMEGS), to be deployed in Wallops Island, and the land-based transponder, LBT-2, will be installed in Kourou. The satellite will be located at 100º West. Essentially there is no functional difference between MRS-1 and MRS-2. Both stations will be remotely operated from OCC. The system functionality is depicted in Fig. 4. It is presently foreseen to support the Meteosat program with one operational satellite, one stand-by satellite and possibly one satellite in hibernation using MRS-1, and to support NOAA with one operational satellite using MRS-2. MRS-2 will also have the capability of ranging more than one operational satellite in 4-way mode.

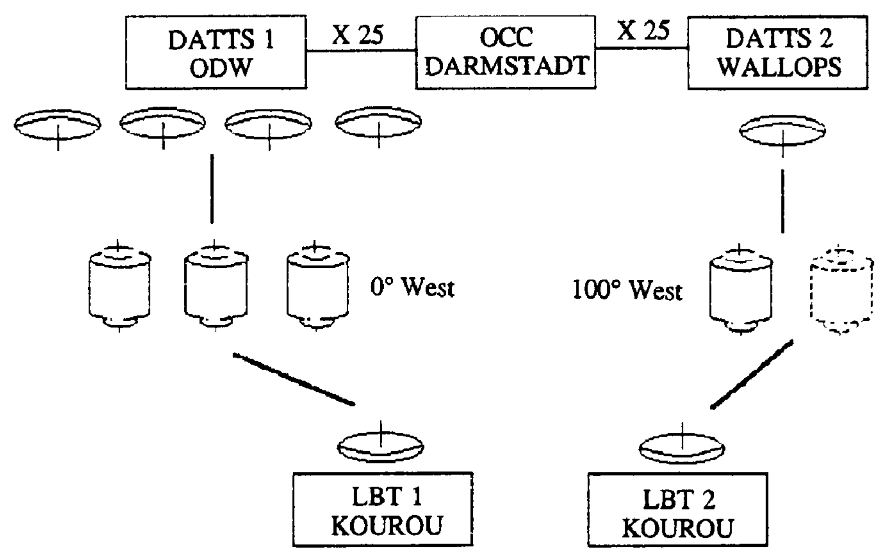


Fig. 4: MRS configuration for Meteosat and NOAA support

3. MULTI-PURPOSE-TRACKING-SYSTEM

The Multi-Purpose Tracking System (MPTS), previously called the Deep Space Tracking System (DSTS), was first used for Giotto, the ESA's Comet Halley interceptor.

The MPTS is deployed across the ESA Tracking network in Perth (Australia), Maspalomas (Canary Island, Spain), Kourou (French Guyana), Kiruna (Sweden), Odenwald (Germany), and Villafranca (Spain). Two MPTSs are also installed in the DLR station at Weilheim, Germany. In addition to operational MPTSs, a Test MPTS has been installed in the reference station at ESOC as well as a test bed at ATNE premises, where the system was developed. A Doppler-only system has also been developed and was recently deployed in the previous NASA station in Fairbanks, Alaska, to support the European Remote Sensing satellite (ERS-1) launch.

CONCEPT

The features that are specific to the MPTS are a hybrid tone-code ranging signal, and a combined Range-Doppler capability.

Ranging signal

The MPTS code consists of a series of square waves sub-harmonically related to and phase synchronized to the tone frequency. The square wave codes are of increasing length and transmitted sequentially, from the shortest code to the longest code, the longest code containing the lowest frequency component and obviously defining the maximum non-ambiguous range of the system.

These codes offer properties of flexibility and fast sequential acquisition (from 10 * 0.5 sec to 1000 seconds for 10 codes). The maximum code length can be selected by the operator. It defines the number of codes that will be transmitted thereby setting the maximum range to be unambiguously resolved. A further advantage of this code structure is the easy code generation [4].

After the transitory stage of tone and code acquisition, the MPTS signal RF spectrum becomes smoother, however the MPTS code does not present spectral properties as good as a pn-code. Analysis of the MPTS signal spectrum and of interference and intermodulation effects on the Telecommand and Telemetry channels is given in ref. [4].

Combined Range-Doppler Capability

The problems of very low signal-to-noise ratios encountered in deep-space missions, and of high Doppler rates present in near-Earth missions cannot be solved by standard Phase-Locked-Loops (PLL). To cope with this difficulty, a new strategy has been implemented in the MPTS. The strategy makes use of the coherent generation of the downlink carrier in the transponder. It is based on a PLL which uses a prediction of the received tone frequency derived from carrier Doppler measurements and correlates the predicted tone frequency with the received ranging signal. A simplified block diagram of the tone PLL is given in Fig. 5. This technique is called "Doppler pre-steered range-tone tracking loop". After frequency acquisition, the tone phase is further adjusted by the PLL, and the code phase is acquired. The MPTS system computer performs the loop filtering, derives the tone frequency from the carrier Doppler data, the station frequency plan including the uplink tone frequency and the transponder turn-ratio, and sets the tone frequency synthesizer accordingly (the loop VCXO function is performed by a frequency synthesizer).

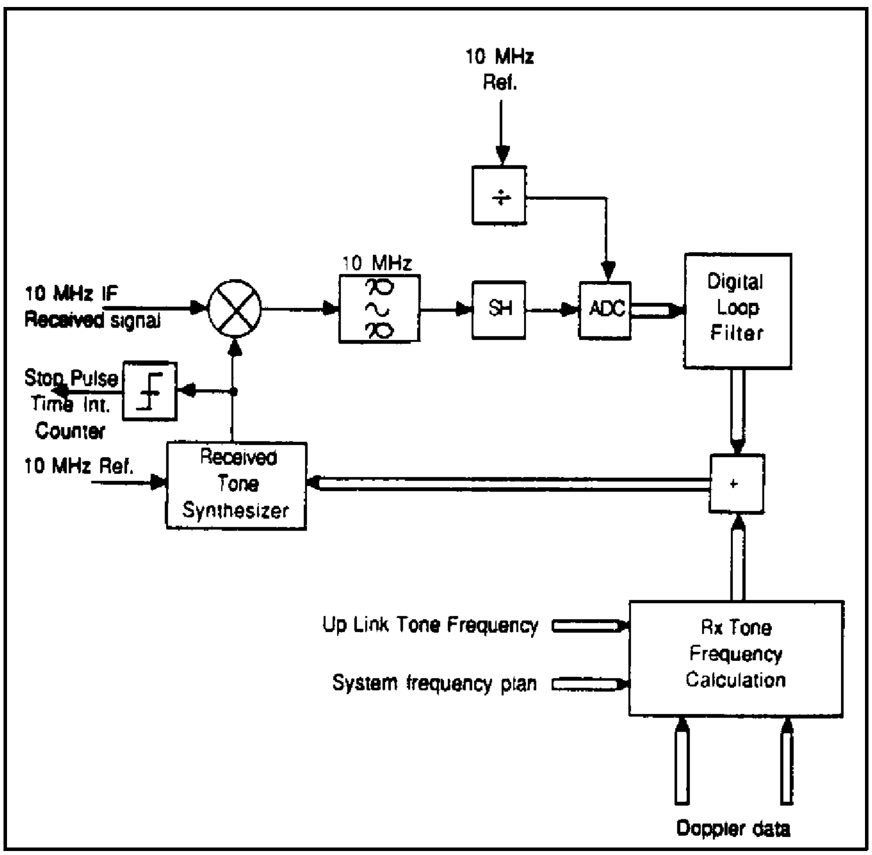


Fig. 5: MPTS simplified tone PLL

Also, the combined range-Doppler capability provides to the orbit-determination process a) integrated-Doppler information that gives sufficient information for near-Earth spacecraft tracking and gives the main information for Deep Space Navigation and b) data to cancel out the atmospheric impairment caused by free electrons along the propagation path, thereby improving system performance. The physical characteristics of this impairment and its correction are best described in ref. [4].

FUNCTIONS and ARCHITECTURE

Essentially, the sequence of events that take place is transmission of an unmodulated tone allowing for tone acquisition, followed by code modulation onto the tone for ranging purpose. At reception, acquisition is started after the expected propagation delay which can be significant in the case of deep space tracking.

These functions are supported by the MPTS drawers (see MPTS block diagram in Fig. 6): the ranging modulator for tone and code generation and for tone modulation, the Doppler drawers for carrier Doppler measurements, the ranging demodulator for tone and code demodulation, the Time Interval Counter for round-trip delay measurements, the MPTS system computer, and finally the timing unit for distribution of time and frequency references to the MPTS drawers.

The Time Interval counter measures the time elapsed between the start and stop pulses. Start and Stop pulses serve the purpose of time markers. They are generated by the tone generator and tone demodulator respectively, and synchronized onto code transmission and code acquisition. For deep space applications, the start pulses are locked onto a highly stable reference provided by the Time and Frequency Drawer. The carrier modulation and acquisition are performed by an external modulator and an external receiver respectively [4]. An overview of the ranging procedure is given in reference [6].

In addition to tracking, the MPTS carries out meteorological measurements using its Meteo Drawer. During a pass, the Meteo drawer can provide pressure, temperature, and humidity measurements from sensors that are placed outside the station. The Meteo data are used by the orbit-determination process in order to model the tropospheric propagation and to derive the atmospheric corrections to be applied to the tracking data [4].

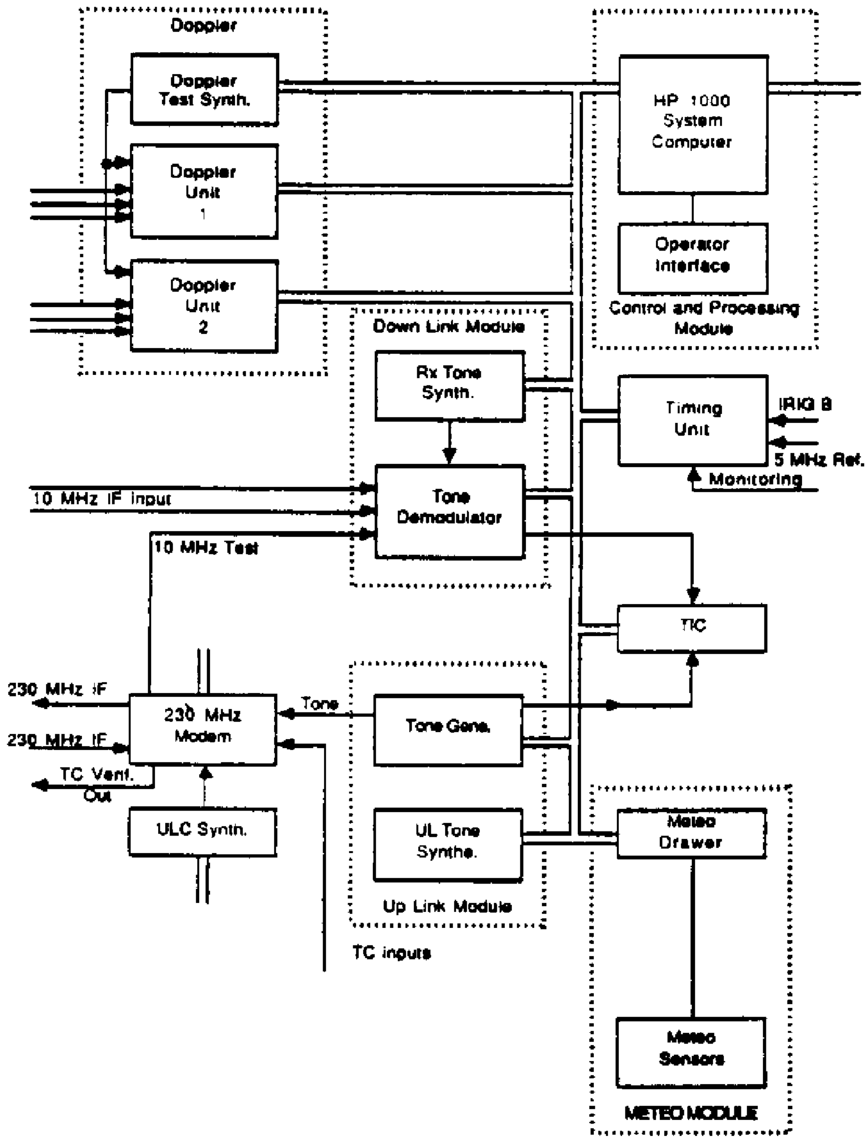


Fig. 6: MPTS block diagram

CAPABILITIES

Operational Modes

The MPTS can be operated in different operational modes providing different sets of data: range-only, integrated-Doppler-only, range and integrated-Doppler. Integrated-Doppler-only mode has been used recently to track ERS-1 during the Launch Early Operational Phase (LEOP). In each of these operational modes, the Doppler Drawer is necessary, even in range-only mode, which uses a Doppler pre-steered range-tone tracking loop [6]. Meteorological measurements can also be performed simultaneously with any other measurement, Ranging or Doppler.

Coherent/non-coherent mode

The MPTS can be operated in coherent or non-coherent mode depending on the satellite transponder. For deep-space applications, coherent mode has to be used in order to predict the tone with the required accuracy and to reduce sufficiently the PLL noise bandwidth. The MPTS has been designed for Giotto, the worst case signal-to-noise density ratio being -10 dBHz. For Giotto, a PLL bandwidth as narrow as 3 MHz needs to be selected, and tone acquisition time is 300 sec.

In near-Earth, both coherent and non-coherent modes can be used [4,6].

Tone Acquisition

The tone acquisition procedure depends on whether the satellite link is coherent or not.

In coherent mode, the Doppler effect on the carrier is known and the exact received tone frequency can be computed and input into the tone PLL (see MPTS concept).

In non-coherent mode, the received tone frequency is known with a frequency uncertainty caused by the Satellite Downlink Carrier bias. In order to minimize the Doppler effect on the tone, a lower frequency tone can be first uplinked. At the reception, the PLL will sweep around the estimated tone frequency until lock is achieved. After acquisition, a higher frequency tone can be transmitted to achieve a higher measurement accuracy. This scheme makes good use of two good properties: 1) a reduced acquisition time and 2) a high range accuracy [6].

Doppler

In coherent mode, the Doppler effect on the tone is proportionally the same as on the carrier and the received tone frequency is easily derived from the frequency plan and the Doppler measurements performed on the received carrier [6].

In non-coherent mode, the tone Doppler is a 2-way effect whereas the carrier Doppler measured on the downlink is a one-way effect. Only an estimation is possible on the carrier Doppler due to the uncertainty of the satellite downlink carrier bias. Detailed explanations on Doppler measurements and on computation of the Doppler effects are given in [6].

Dual Doppler capability

For near-Earth applications, the Doppler effect may be greater than the frequency sweep range capability of the station receiver. In order to accommodate high Doppler effects (more than +/- 150 KHz) that are encountered at Ka-band (for example in the case of the Eureca/Olympus experiment), a Doppler correction is performed on the carrier before the signal is fed into the station receiver: Doppler data are obtained from the front end equipment are used to adjust the Local Oscillator frequency of a downconverter, thereby compensating for the Doppler effect.

Two Doppler Drawers are then required: one to evaluate the first Doppler correction, another to measure the residual Doppler on the received carrier. Detailed explanation is given in [6], as well as a station frequency plan and station block diagram.

The dual-Doppler capabibility can also be used to simultaneously measure the Doppler shift on two carriers for compensation of the ionosphere and interplanetary plasma. But, as yet, the Agency has not had a satellite with two simultaneous coherent downlinks.

PERFORMANCE

System performance have been analyzed in [4], in particular the probability of incorrect ambiguity resolution, ranging- and Doppler-measurement accuracy, and interference and intermodulation effects on the telecommand/telemetry channels.

The requirements in terms of ranging are +/- 0.5 m (or 3 nsec) for all ranges up to a few billion km [5]. The MPTS tone frequency and the PLL tone loop bandwidth can be set to accommodate this requirement: tone and code acquisition can be performed down to a S/No of -10 dBHz. Refer to [4] for theoretical and measured jitter results.

The maximum non-ambiguous range that the MPTS can measure is 1.5 million km. For deep-space applications, the range ambiguity is further resolved by the orbit-determination process.

SOFTWARE ARCHITECTURE

The MPTS software has been redesigned in 1989 to include new user requirements, in particular an advanced user interface. New software features have been introduced giving higher flexibility and reliability. This new software version is referred to as Mark III. Some of its features are described below.

MPTS table

Previous sections have given an overview of the MPTS with its functions, capabilities and operational modes. The operational MPTS set-up is derived by the software from a table of parameters, which can be edited by a local operator or by the OCC operator at the time of the operational request.

Some parameters have already been introduced: they are related to the station frequency plan, the operational modes, coherent/non-coherent mode, dual or single Doppler mode, Ranging only, Doppler only, Ranging with Doppler measurements. Other parameters define the uplink tone frequency, the start tone frequency (to be used for non-coherent acquisition), the tone PLL bandwidth, the expected propagation delay, the maximum code length. Additional parameters specify the duration of each measurement (Ranging, Doppler, Meteo), the sampling period to be used for each measurement, the size of the data sets which collects the measured data [6].

An advanced table management has been designed and implemented. Its features are best described in [6,7,8].

Data Acquisition Process - Data Set

Data Acquisition Processes (DAP) have been implemented in order to control and monitor the drawers for signal acquisition, and to collect the data and store them in Data-Sets.

MPTS interfaces

The MPTS interfaces with a Satellite-Dedicated Control System (SDCS) in the OCC and with the Station Computer (STC).

The SDCS operator sends the DAP requests to the Dap Queue, and receives the Data Sets. It also receives Configuration reports sent regularly from the MPTS, and can request a data set catalog, delete data sets, modify and purge the DAP queue.

The STC Interface is mainly to 'call' one of the pre-stored tables; individual parameters can also be changed. Table management is carried out on the MPTS console or on the console of another MPTS in the network, for example in the reference station.

MPTS : PRESENT and FUTURE

Presently, the MPTS ranges several LEO satellites, such as ERS-1, the first European Remote Sensing satellite designed to provide images in the microwave spectrum mainly for oceanographic research, Eureca-1 the ESA scientific payload launched by the shuttle (EUropean REtrievable CArrier), Hipparcos, an ESA astrometry satellite (HIgh-Precision PARallax COllecting Satellite). It is also used for LEOP. It will be used for tracking Giotto, currently retargeted towards Comet Grigg-Skjellerup, for an encounter in July 1992. It is also planned to support other missions such as Cluster.

The MPTS is based on the DSTS Hardware which has been designed in the early 80’s. ESA is considering a study for the next version of MPTS. More intelligent and autonomous drawers, more performant acquisition strategies making use of high IF frequency sampling, direct digital synthesizers NCO, and fully digital tracking loop, and possibly FFT acquisition techniques are being considered.

4. DATA RELAY SYSTEM

INTRODUCTION

In an effort to support its space program from the mid 1990’s onwards, the Agency has defined the concept of a Data Relay System (DRS) and is currently developing a proof-of-concept satellite, called Artemis. Artemis will provide data communication between user spacecraft in Low Earth Orbit (LEO) and ground-based terminals. It will also support LEO tracking. Inter-Orbit Communication will be tested at optical frequencies with the user satellite SPOT-4 (from 1995 onwards), and possibly with Eureca follow-on missions at Ka-band.

The DRS concept is based on the use of two geostationary DRS satellites (DRSS) to provide quasi-continuous coverage for LEO spacecraft. Also compatibility with the American TDRSS and the Japanese DRTSS relay systems is intended, thereby allowing for European and non-European users. Planned European users are the European Polar Platform, the European space plane Hermes, and the Columbus Free Flyer module. Mission, development strategy, technologies and design of the overall Data Relay System are best described in [9].

The Agency’s long term space program is being revised. Its DRS program is being questioned. The Agency is definitively seeking international cooperation, and a Data Relay System is an ideal project to be proposed at the international level, for international partners could plan a truly global relay satellite system. Such a strategy would benefit the international community by providing a fully-continuous and worldwide coverage without any zone of exclusion. The next section deals mainly with the tracking aspects of the DRS satellites and the DRS user spacecraft studied by the Agency.

TRACKING REQUIREMENTS and SYSTEM ARCHITECTURE

Tracking includes both Doppler and Ranging measurements. Tracking requirements for user spacecraft, such as Earth observing satellites, the European space plane Hermes, and the Columbus free flyer module, are analyzed in [10]: in the case of a Ka-band Inter-Orbit-Link (IOL), the instrumentation accuracy should be 2 m for ranging and 2 mm./sec for Doppler, and in the case of an S-Band IOL it should be 2 m for ranging and 4 mm/sec for Doppler. The overall system errors are slightly larger for they include the instrumentation errors and other source of errors such as atmospheric/plasma degradation (see [10]). From the tracking performance requirements on the user spacecraft, requirements on the DRSS position accuracy are derived. The instrumentation errors should be less than 1 m in range and 1 mm/sec in Doppler [10].

To meet the accuracy requirements, the Agency has proposed a system architecture based on three ground-based tracking terminals: a Primary Ranging Terminal (PRT) co-located with the Tracking and Telecommand (TTC) station at Fucino, Italy, and two Remote Ranging Terminals (RRTs), RRT1 co-located with the TTC backup station in Villafranca, Spain, and RRT2 located in Redu, Belgium. The two geostationary DRS Satellites, DRSS-West and DRSS-East, would be located respectively at 44º West and 59º East, both visible from Europe, and would relay telemetry, housekeeping, and ranging signals to the user spacecraft. The tracking of a user spacecraft would be performed from a User Earth Terminal located at the user's premises.

DRS RANGING SIGNAL

Two concepts are considered. One is a multiple satellite access ranging system based on the MRS concept and the other is a 2-way tracking system based on the MPTS.

The MRS type of concept plans to use the RRTs as land-based transponders. The DRSS would transposed simultaneously up to three pseudo-random ranging codes, code 1, code 2, and code 3 generated respectively by PRT, RRT1, and RRT2. This system would provide 2-way (1 set) and 4-way (2 sets) ranging data.

The MPTS approach is to perform 2-way measurements only, from each of the three tracking terminals. The Agency is thinking of using the MPTS. However a more recent real-time computer will have to be used. A next generation MPTS with enhanced performance and state-of-the-art design and technology is also being considered.

The Agency has investigated whether the same type of ranging signal could be used for both DRSS and DRS user spacecraft.

5. SUMMARY

The ESA Multi-Purpose Tracking System has proven its performance in both deep-space and near-Earth missions since 1986, validating the concepts of hybrid tone-code ranging signals and of "Doppler pre-steered range-tone tracking loop", enabling the tracking of many satellites from the various ESA ground stations. The Agency has also developed and deployed the Meteosat Ranging System in 1989 allowing simultaneous multi-point ranging in a channel shared with meteorological services.

Both systems present advantages: the MRS for its very good spectral properties and multiple-satellite access capability, the MPTS for its high sensitivity to deep-space signals and high tracking capability in presence of high Doppler rates encountered in Low Earth Orbit satellites. Both systems have evolved with the user requirements. Today, the Agency is discussing the European Data Relay System.

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NOMENCLATURE

ADC	Atlantique Data Coverage (NOAA support)
AFCU	Automatic Frequency Control Unit (MRS)
ATNE	Applications des Techniques Nouvelles en Electronique, Paris
BPSK	Binary Phase Shift Keying
CDMA	Code Division Multiple Access
DATTS	Data Tracking and Telecommand Station, Odenwald, Germany
DLR	Deutsche Luft Raumfahrt (German Air and Space Organization), Weilheim, Germany
DRS	Data Relay Satellite
DRTSS	Data Relay Tracking Satellite System, Japanese system
ESA	European Space Agency
ESOC	European Space Operational Center, Darmstadt, Germany
ESTEC	European Space Technical Center, Noordwijk, The Netherlands
EUMETSAT	European Meteorological Satellite Organization, Darmstadt, Germany
GOES	Geostationary Operational Environmental Satellite
LBT	Land- based Transponder, Kourou, French Guyana
METEOSAT	Meteorological Satellite
MPTS	Multi-Purpose Tracking System
MPT	Mission Performance Telecommunications Transponder
MRS	Meteosat Ranging System
MST	Mission Support Telecommunications Transponder
NOAA	National Oceanographic and Atmospheric Administration
OCC	Operational Control Center, Darmstadt, Germany
ODW	Odenwald, Germany
PLL	Phased Lock Loop
RAMOD	RAnging MODulator (MRS)
SPL	Split Phase Level
STC	Station Computer
TDRSS	Tracking Data Relay Satellite System, American system
WEFAX	Weather Facsimile chart