MICROWAVES TO MEGABITS

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ABSTRACT

The Mark III system has 14 IF to video converters, each with built-in synthesized local oscillators which have a range of 100 to 500 MHz covered in 10 kHz steps. In the normal wideband-continuum mode, all 14 upper and all 14 lower sideband video outputs (each with 2 MHz bandwidth) are recorded with a total data rate of 112 Mbits/sec.

In the NASA geodetic observations, two IF bands are simultaneously recorded from a dual band (S/X) receiver.

INTRODUCTION

In the Mark III configuration for geodetic observations, a dual frequency wideband receiver is used with the Mark III terminal for acquisition and recording of the very long baseline interferometer (VLBI) signals at the observing station.

RECEIVER

The dual receiver was designed and built for use at the prime focus of antennas with f/D≃0.4. The first unit was built for use at the Owens Valley Radio Observatory's 130′ (45.24 m) antenna. The receiver is designed to operate simultaneously at 13 cm (S-band) and 3.6 cm (X-band). The receiver is packaged along with feeds into a complete front-end box. Table 1 lists the characteristics of the receiver.

Table 1
Summary of Receiver Characteristics

FREQUENCIES	
S-band LO	2020 MHz
X-band LO	8080 MHz
LO Reference	5 MHz
S-band IF	200-550 MHz (3 dB bandwidth)
X-band IF	100-550 MHz (3 dB bandwidth)
Approximate 3 dB S-band frequency range (including feed and paramps) – 2220-2320 MHz	
Approximate 3 dB X-band range – 8180-8600 MHz	
NOISE TEMPERATURE	
S-band system temperature	80 K measured on OVRO 130′ (45.24 m)
X-band system temperature	160 K measured on OVRO 130′ (45.24 m)
FEEDS	
On axis S/X dual frequency feed: Polarization – RCP on antenna (feed is LCP)	
Off axis X-band feed: Polarization – LCP on antenna (feed is RCP)	

The X-band low noise amplifiers are two separately-packaged parametric amplifiers. Each stage has a noise temperature of about 120 K and a gain of 13±1 dB. The paramps are fixed tuned to cover 8.05 to 8.55 GHz with less than ±1 dB variation over this band.

The X-band channel has a latching circulator in front of the paramps to allow for "Dicke" switching between the on-axis S/X feed and an off-axis X-band feed.

The S-band low noise amplifier is a two-stage parametric amplifier. The paramp operates at about 14 dB per stage, has a 50 K noise temperature and covers a frequency range in excess of 2.2 to 2.3 GHz.

Both S and X channels have a coupler and four-way divider for injection of noise sources and delay calibration signals.

The receiver local oscillators are derived from 5 MHz using a phase-locked oscillator. The S-band oscillator is phase-locked using a harmonic mixing scheme with 80 MHz reference and 20 MHz IF. By successive doubling and filtering, 20 and 80 MHz are derived from 5 MHz. The phase locked oscillator is used directly as the S-band LO and is multiplied by four to provide the X-band LO. The oscillator can be locked every 40 MHz within its limited tuning range. The lock point at 2020 MHz was chosen as the best choice for the frequency range covered by the low noise amplifiers.

The receivers have broadband (5-500 MHz) IF amplifiers. A total of 71 dB gain is provided in S and X channels respectively – 40 dB of this gain is built into the mixer preamplifiers.

The IF output level is about −10 dBm for both S and X channels. However, owing to the rapid increase of cable attenuation with frequency above 100 MHz the X-band IF is corrected on the ground using a cable compensation filter. The compensation filter has a loss of 20 dB at 200 MHz and 8 dB at 450 MHz. The S-band IF is not compensated owing to its relatively small bandwidth.

MARK III TERMINAL

In the VLBI configuration used for high accuracy geodesy, the two receiver IF output signals are sent to the inputs of the Mark III terminal. This terminal converts the signals to 28 baseband channels, digitizes the channel signals, formats the digital data, and records the data on magnetic tape.

The IF output from the receiver is connected to an IF distribution module which amplifies and splits the IF power to all frequency converters modules. The distributor is dual channel to allow for the IF's from two radiometers or from two polarizations, etc. In addition, each channel is split into two subchannels, one covering the range 96 to 224 MHz and the other covering the range 216 to 504 MHz. This split is required to reduce the loss in signal-to-noise ratio that results from the odd harmonic response of the IF-to-video converters which contain no preselection filters. The 14 converters can be connected to either channel and subchannel via a cable patch.

Included in the distributor are two wideband square law detectors which can be used for total power monitoring. When used in conjunction with the front end, the detector outputs can be processed by the built-in integrator and microprocessor controlled ASCII transceiver to compute the system temperature and to do radiometry.

The Mark III terminal has 14 video converters each with built-in synthesized local oscillators which have a range of 100 to 500 MHz covered in 10 kHz steps. In the normal wideband-continuum mode of 14 upper and all 14 lower sideband video outputs are used, one going to each recorder channel. Other modes are ones in which fewer tracks are recorded simultaneously if fewer bands are needed. In these modes, all the physical tracks on the tape are recorded after many forward and reverse passes of the tape.

The video converter converts a window in the IF input to video. The conversion is a frequency translation from IF to video using the "phasing" method of single sideband conversion. Both upper and lower sidebands are preserved, low pass filtered, and amplified. The analog video signals are clipped, sampled, and formatted in the same way for each recorder track so that each track can be decoded independently. The Mark III serial data format shown in figure 1 contains complete time of day, auxiliary data, cyclic-redundancy check bits and parity check bits along with the sampled video data bits.

The Mark III terminal uses instrumentation tape recorders presently outfitted with 28-track heads; each track is used to record a 2-MHz bandwidth at 4 MB/s with a longitudinal density of 33,000 bits per inch so that the total recorded bandwidth is 56 MHz, as opposed to the 2 MHz obtainable with Mark II. The system is quite flexible in allowing slower record speeds, and the corresponding narrower bandwidths, for operations that do not require the full bandwidth.

Table 2 summarizes the characteristics of the Mark III terminal.

The Mark III terminal is contained in four equipment racks. Two racks contain the two tape recorder systems, each consisting of a recorder transport, record head drivers, recorded controller and read-after-write/playback electronics. The third rack contains the IF distributor, video converters, formatter and decoder. The fourth rack contains the system control computer and the operators console. Every module in the Mark III can be locally controlled from its front panel or remotely controlled by means of a two-way serial communication system. Thus, a Mark III terminal can be operated manually or can be placed entirely under computer control except for the manual tape changes. When used under computer control, it is very easy for the terminal to follow complicated schedules including starting and stopping the tape and changing mode. It is relatively easy for the user to tailor the mode of operation of the terminal to the observing program requirements in order to make best use of the capabilities of the Mark III and to minimize the amount of tape required for an experiment.

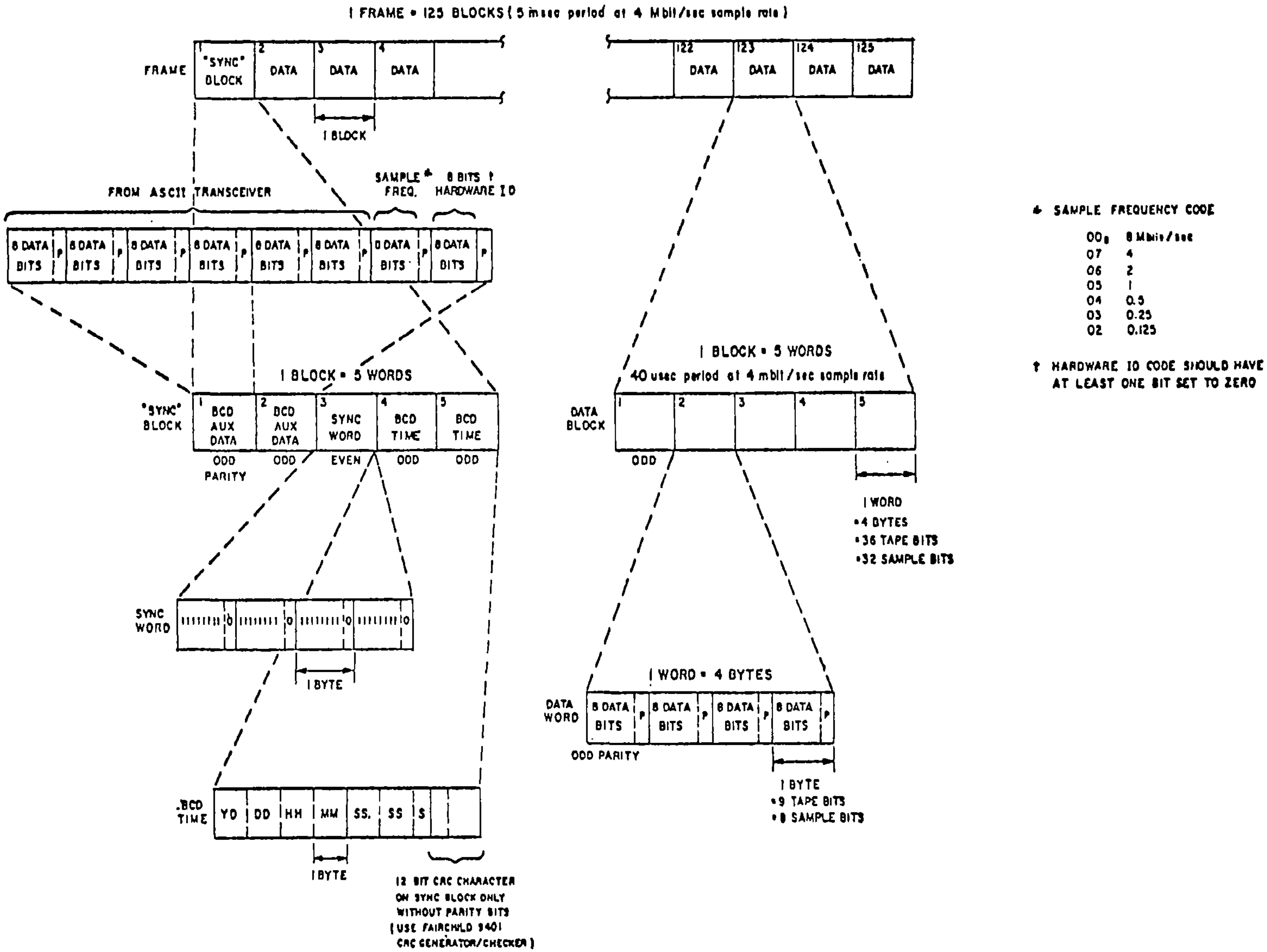

Figure 1. Mark III tape format (single track).

Table 2
Mark III Terminal Characteristics

Recorder Type: Instrumentation

Tape: 1 inch Ampex 797 or equivalent (Ampex 795 on GSA), 9200 ft. on glass reels (Corning #690449)

Number of Tracks: 28 according to EIA standard

Track Width: 25 milli-inches or 635 micrometers

Longitudinal Density: 33,000 bits/inch on each track

Record Code: NRZM ("1" = flux change "0" = no flux change)

Format: see figure 1

Standard Sample Rate: 8,4,2,1,0.5,0.25,0.125 MHz

Video Low Pass Filter Bandwidths (10 dB bandwidth) 4,2,1,0.5,0.25,0.125 MHz

Filter Type: 7-pole Butterworth with 3 dB point at 0.45 x sample rate. In the systems presently being manufactured, 4 converters are fitted with all filters in the upper sideband channel while all the remaining channels are initially outfitted with 2 MHz filters. An external 62.5 kHz filter has to be used for the 0.125 MHz sample rate.

Number of IF to video converters: 14 (each produces separate upper and lower sideband outputs)

Converter LO range: 100-500 MHz selectable in 10 kHz steps.

Number of IF channels: 2 (each converter can be connected to either IF via patch panel)

Operating modes: Wideband – 28 tracks recorded in one pass remaining 14.
Continuum – 14 tracks recorded per pass only seven converters used.
Multiline – 4 tracks recorded in each pass the upper sideband outputs from four converters.
Spectral – 1 track recorded per pass–Mark II compatible mode.

Control Computer: Hewlett Packard 1000

MARK III SYSTEM SENSITIVITY

The new Mark III acquisition terminal has been developed to make, initially, a more than five-fold improvement (compared with the Mark II system) in the sensitivity of VLBI for astrophysical, astrometric, and geophysical applications. When this is used with the Mark III wideband receiver, the total system has very high delay resolution even when small antennas are used. As an example, table 3 lists the performance characteristics when the Mark III system is used with 4-meter and 18-meter antennas.

Table 3

Source = 4C39.25 = 10J
Ant. 1 = Westford = 18 m = 50% eff.
Ant. 2 = Transportable = 4 m = 60% eff.
Ts1=Ts2 = 160 K
Ta1 = 0.45 K
Ta2 = 0.03 K
Correlation Amplitude = 0.12%
Integration time = 500 sec.
Recorded bandwidth = 56 MHz
Signal to noise ratio = 114
RMS spanned bandwidth = 100 MHz
Δt (group delay) RMS = 14 PS or 4 millimeters

MARK III TERMINAL SCHEDULES

The first Mark III terminals are being built for use in the NASA Crustal Dynamics Project for high accuracy geodetic measurements with both fixed and mobile VLBI stations. The systems are in stand-alone, modular form so that they can be easily transportable to any antenna. Table 4 lists the current schedule for completion of the first nine Mark III terminals.

Table 4

Mark III Terminal	ID Number	Expected Completion Date	Sponsor
Haystack	Mk-III-0	Complete	NASA
OVRO	Mk-III-1	July 1979	NASA
Onsala	Mk-III-2	September 1979	USAF/NSF
Transportable	Mk-III-3	September 1979	USGS
Ft. Davis	Mk-III-4	January 1980	NASA
ARIES	Mk-III-5	July 1980	NASA
Bonn	Mk-III-6	July 1980	MPI
NRAO 140	Mk-III-64	Complete	NSF
NRAO VLA	Mk-III-65	1980	NSF