Chapter 24

A Control and Monitor System for the GMRT

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24.1 Introduction

Modern radio telescopes are complex assemblies of electronic and electro-mechanical subunits. To allow a successful observation, all of these sub-units have to be "set" as per the users requirements. For example, the antennas have to track the selected source, the front-ends have to be tuned to the chosen frequency band, all the amplifiers along the signal path have to be set at the value which would give the optimum signal to noise ratio, the local oscillators have to be tuned to select the desired frequency, the correlator has to be set up to do the appropriate fringe and delay tracking etc. In an interferometer like the GMRT this means that one has to, in a co-ordinated manner, control sub-systems which are several tens of kilometers separated from one another. In addition, it would be highly desirable for the health of the critical sub-systems to be able to be periodically monitored, so that should any subsystem fail, the affected data can be flagged, and also of course remedial action could be taken to fix the faulty unit. Further since it is not humanly possible to remember all the various safety limits of each of the sub-systems, one requires the telescope control system to not permit operations which could endanger the safety of the telescope or the human operators. The GMRT Monitor and control system was designed with all these different requirements in mind.

The GMRT control and monitor system (also referred to as the "telemetry system") allows one to

1. Rotate of all the thirty antennas in azimuth and elevation, and/or to track a celestial source.
2. Bringing the required feed in the feed turret to the focus via the Feed Position System(FPS).
3. Select front end system parameters like the observing frequency band, desired noise calibration, etc.
4. Sets the IF sub-systems including the LO frequencies, the IF bandwidths and attenuation, the ALC[1] operation etc.

[1] Automatic Level Controller

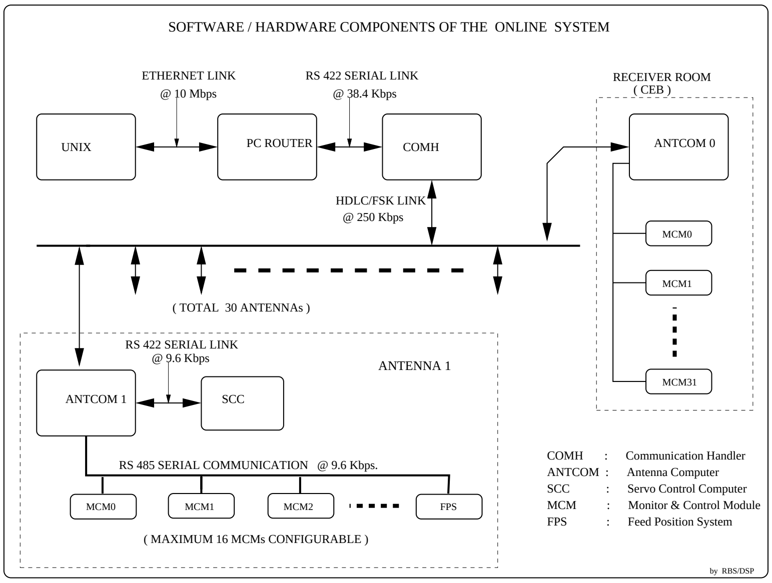

Figure 24.1: Block diagram of the GMRT monitor and control System. See the text for more information.

5. Sets the baseband bandwidth and attenuation.

6. Monitor, literally, hundreds of system parameters at all points along the signal flow path.

7. Have a voice link between each antenna shell and the control room in the CEB (Central Electronics Building).

24.2 Overview

The major components of the Monitor and Control system (see Figure 24.1) are ONLINE (a unix level program that provides the user interface), PCROUTER, a PC based router, COMH, a communications handler that deals with the packet based communication between the Unix workstation on which ONLINE is running and the Antenna Based Computer (ABC, also called ANTCOM) located in each antenna shell, and finally several Monitor and Control Modules, (MCM) which provide the monitoring and control interfaces to the various sub-units (i.e. the LOs, amplifiers, etc.).

We now look at each of these sub systems in slightly more detail.

24.2.1 ONLINE

The ONLINE software running on a UNIX workstation provides the user interface for the control and monitor system. The commands typed by the user are sent to the relevant antenna(s) by the telemetry system. The monitoring data from all the various GMRT subsystems are also logged by ONLINE. Should some critical subsystem fail, ONLINE will raise an appropriate alarm so that remedial action can be taken.

24.2.2 PCROUTER

This converts the data from the format used for TCP/IP (ethernet) communication to one suitable for the serial communication links used by the GMRT telemetry system. As the name suggests this is PC based.

24.2.3 COMH

COMH is the communication handler and it handles all the communication between the UNIX workstation on which ONLINE is running and the various Antenna Base Computers (ABCs). COMH operates in a time division multiplexing (TDM) mode i.e. it sends the formatted user commands to the first antenna and then waits for an acknowledgment. If it receives an error free reply before the timeout period it selects the next antenna and the operation continues. In case COMH doesn't get a reply before the timeout period or if the reception is erroneous then it tries the same antenna again. After a total of three failures COMH passes on a Timeout or Checksum error (as appropriate) to ONLINE and then moves on to the next antenna.

24.2.4 ANTCOM or ABC

There is an ANTCOM (also called an ABC) located in each antenna shell. All communication between the antenna and ONLINE is routed through the ANTCOM in that antenna. The ANTCOM receives various parameters sent by COMH, performs some computations if necessary, and passes on the commands to the appropriate sub system of the antenna. In detail, the ANTCOM has three communication links, viz. (a) the main link between COMH & ANTCOM which operates at 250 kbps, (b) an asynchronous 9.6 kbps RS 422 communication link between ANTCOM & the Servo Control Computer (SCC) and (c) an asynchronous 9.6 kbps RS 485 communication link between ANTCOM & upto 16 Monitor and Control Modules (MCMs).

In addition to the ANTCOMs in the various antennas, there is also an ANTCOM (called ABC0) in the receiver room of the CEB. ABC0 handles the configuring of the baseband system in the receiver room.

24.2.5 Servo Control Computer

In addition to an ANTCOM, each antenna has a Servo Control Computer (SCC) which is responsible for controlling the motion of the antenna. The SCC accepts movement commands, position information etc. from the ANTCOM, checks that the command is sensible, and if so obeys it. It also returns the antenna status information periodically through the same link. This information is passed on by the ABC to ONLINE and is displayed on a monitor in the CEB.

24.2.6 Monitor and Control Modules

MCMs are a general purpose Micro-controller based card which provides 16 TTL Control O/Ps and can monitor upto 64 analog signals. These MCMs are the interface to all the settable GMRT subsystems, like the front ends, the LOs the attenuators etc. In detail, at each antenna, MCM 5 is the interface to the front end system, while MCMs 2,3, and 9 are the interface to the LO and IF systems.

The Feed Positioning System (FPS) which is used to position the feed turret so that the desired feed is at focus is also controlled by the ANTCOM.

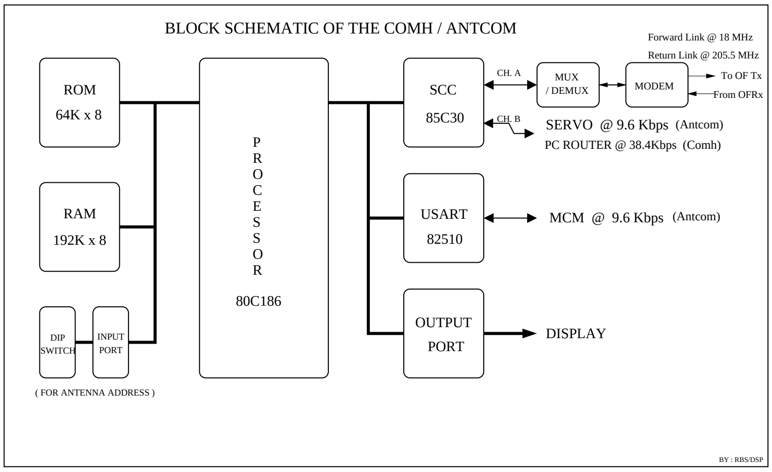

Figure 24.2: Block diagram of the GMRT communication handler (COMH). The antenna computer (ANTCOM) has essentially the configuration.

24.3 Signal Flow in the GMRT Control & Monitor System

User commands for various antennas are processed by ONLINE running on a UNIX workstation and are sent to the COMH via the PCROUTER. The PCROUTER acts as a buffer and accepts the TCP/IP data on a 10/100 Mbps (i.e. a standard ethernet) link, strips the TCP/IP header and sends the data to COMH on a 38.4 kbps link. This uses a standard RS232-C link on the PC side and a conversion to RS 422 signals (differential TTL signals) on the COMH side.

COMH (see Figure 24.2) is basically an 80C186, 16 bit micro-controller based card, which works at a clock speed of 6 MHz. This card also contains a Zilog 85C30 dual channel communication controller. The two channels are respectively for SDLC/HDLC communication at 125 kbps (for communication with the ANTCOMs at the different antennas) and a asynchronous communication at 38.4 kbps (for communicating with the PCROUTER). COMH also has an Intel 29C17 CODEC (voice coder-decoder) to handle voice communication at 62.5 kbps, circuitry for digital Phase Lock Loop and other combinational logic to handle clock recovery and bit interleaving functions, as well as FSK modem chips NE 5080 and NE 5081 to handle FSK modulation and demodulation. COMH multiplexes command data, digitized voice, synchronization pulses, dial pulses and two aux channels into a single bit stream. This bit stream is then converted (via FSK, see section 24.4.1 for details) to an analog signal at 18 MHz.

The block diagram for this multiplexing of voice and data is shown in Figure 24.3. The structure of the multiplexed bit interleaved data frame is shown in Figure 24.4. At the bottom of this figure is shown the flow diagram for the synchronous detector state machine.

The FSK analog signal is sent via the fiber optic link to the ANTCOM at the antenna base. The ANTCOM has the same circuitry as COMH but unlike COMH it handles two serial communication links (using an INTEL 82510 Communication Controller) i.e. the ANTCOM-MCM communication link and a serial link to the Servo Control Computer (SCC). ANTCOM demodulates the FSK signal into 250 kbps data, regenerates the 250 kHz clock using a digital Phase Lock Loop, looks for sync bits and if it finds a match with no error or one bit error then it demultiplexes the data into command, voice, dial pulse and aux data and passes each to the appropriate circuit for further processing (see Fig-

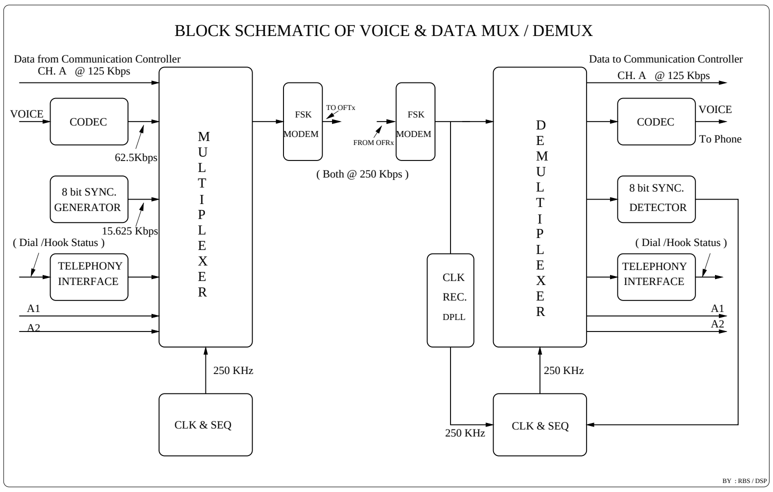

Figure 24.3: Block diagram of the voice and data multiplexer.

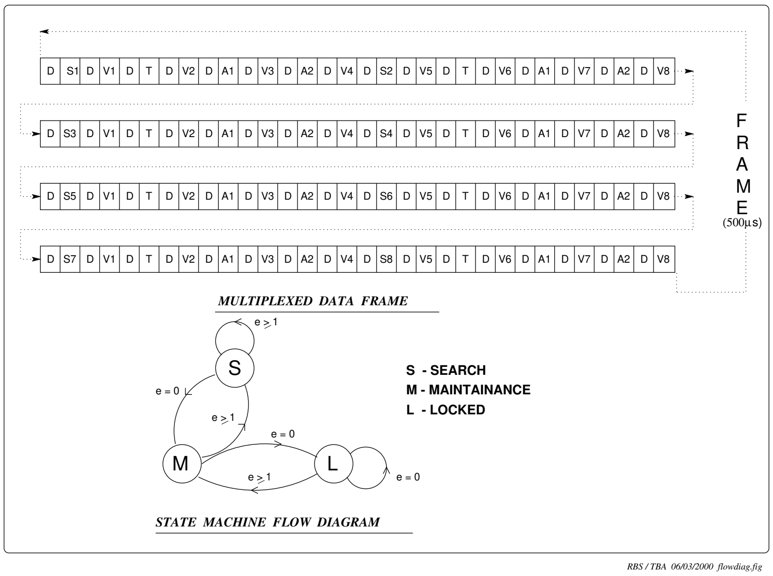

Figure 24.4: Structure of the multiplexed voice and data frame. Shown at the bottom of the figure is the flow diagram for the synchronous detector state machine.

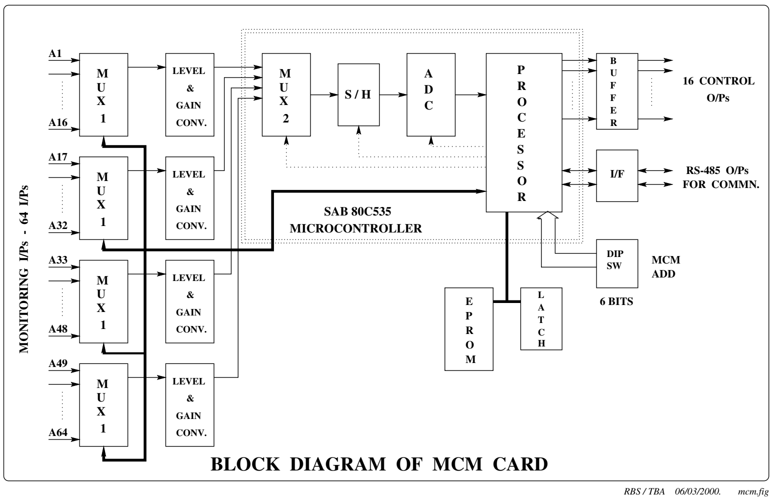

Figure 24.5: Block diagram of the monitor and control (MCM) cards.

ure 24.3). The ANTCOM communicates with and controls the various subsystems in the antenna (other than the servo subsystem for which there is the dedicated SCC) via the MCM cards. A block diagram of the MCM card is shown in Figure 24.5. The MCM card is a general purpose 80C535 Micro-controller based card which provides 16 TTL Control O/Ps and monitors upto 64 analog signals. It also has an RS485 communication link for communicating with the ANTCOM.

For the return link, the ANTCOM takes the monitoring information from SCC, MCMs and FPS forms a packet of SDLC/HDLC data and multiplexes with voice, hook status and aux channels into a single bit stream. This bit stream is converted into an FSK analog signal at 4.5 MHz, which is then up converted to 205.5 MHz using the regenerated 201 MHz as the LO (see Figure 24.8). This analog signal is sent along with the astronomical signals to the CEB. At the CEB thirty CEBCOMs (one for each antenna) demodulate the FSK signal to convert it back into a digital 250 kbps data stream which is passed on to COMH via a 32 way multiplexer (MUX 32) card. The voice signals from the antennas are routed to the EPABX (telephone exchange) system. The block diagram for this telephonic communication is shown in Figure 24.6. The voice signals are digitized using an INTEL 29C17 CODEC IC using a 7.8 kHz clock to produce a 62.5 kbps data stream. The CODEC uses “A law” for data companding/expanding.

24.3.1 Error Detection

The error detection uses both Cyclic Redundancy Check (CRC) and checksum methods. SDLC/HDLC supports 16 bit CRC error detection. CRC can detect all the single errors, double errors and burst errors up to 16 bits in length and can also detect 99% of burst errors of lengths greater than 16 bits.

The way this works is as follows. A cyclic code message consists of a specific number of data bits $G(X)$ and a Block Check Character (BCC). Let n equal the total number of bits in the message, k equal the number of data bits, i.e. $n-k$ is the number of bits in the BCC. The code message is derived from two polynomials which are algebraic representations of two binary words, the generator polynomial $P(X)$ and the message polynomial $G(X)$. The generator polynomial $P(X)$ is a type of code used in CRC-12, CRC-16 and CRC-CCITT.

For example, n bits of binary data can be represented as a message polynomial of

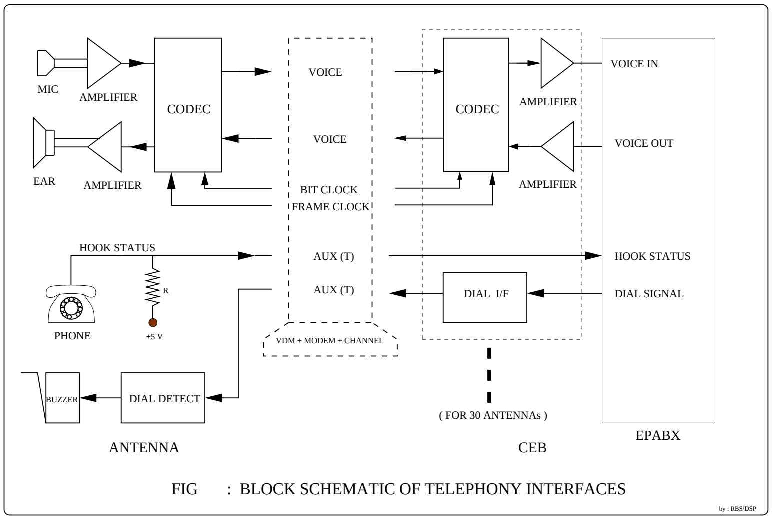

Figure 24.6: Block diagram of the telephony interfaces.

degree $n-1$. Thus, an eight-bit long message 10101010 is represented as

$$G(X) = X^7 + X^5 + X^3 + X^1. \tag{24.3.1}$$

The code message can be constructed as follows:

1. Multiply the message $G(X)$ by X^{n-k} where $n-k$ is the number of bits in the BCC.
2. Divide the resulting product $X^{n-k}[G(X)]$ by the generator polynomial $P(X)$.
3. Disregard the quotient and add the remainder $C(X)$ to the product to get the code message polynomial $F(X)$, which is represented as $X^{n-k}[G(X)] + C(X)$.

The division is performed in binary without carries or borrows. The code message $F(X)$ is transmitted as binary data and the receiver at the other end retrieves the message using the same generator polynomial and accepts the data if the remainder is zero.

24.4 Signal Modulation

As described above, the Control and Monitor system hardware essentially consists of a digital part, an analog part and the Optical Fiber system (see Figure 24.7).

The optical fiber is a single mode analog link operating at 1310 nm, and can carry signals from a few MHz to about 1 GHz. There are two fibers (an ‘forward link’ and a ‘return link’) between the Central Electronics Building (CEB) and each antenna. In the forward link the telemetry signals use an 18 MHz carrier, and the return link has a 205.5 MHz carrier. See Figure 24.8 for a schematic of the different signals carried by the forward and return links.

24.4.1 Frequency Shift Keying

As mentioned above, the digital data that the telemetry system generates is converted to an analog signal using Frequency Shift Keying (FSK). FSK is a special type of modulation

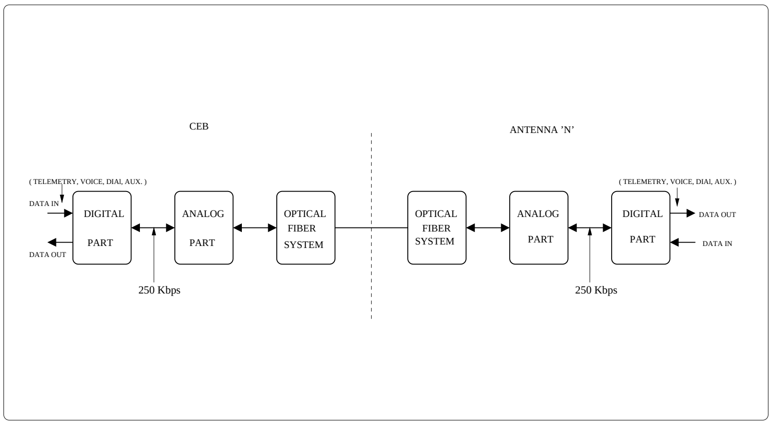

Figure 24.7: Schematic of the GMRT telemetry system. See the text for more information.

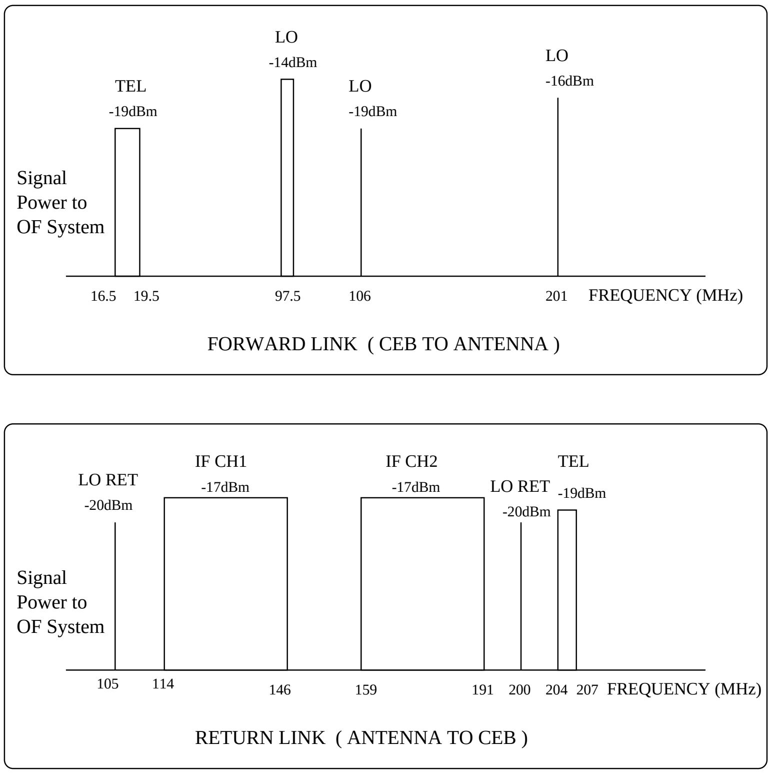

Figure 24.8: Schematic of the signals carried by the forward and return link. See the text for more information.

where the digital signals ("0" & "1") changes the frequency of the pseudo carrier to one of two frequencies, usually denoted as MARK and SPACE respectively.

If T is the duration of a bit, then the bandwidth (BW) occupied by the FSK signal is:

$$\left[\nu(\mathrm{MARK}) + \frac{1}{\mathrm{T}}\right] - \left[\nu(\mathrm{SPACE}) - \frac{1}{\mathrm{T}}\right] = \nu(\mathrm{MARK}) - \nu(\mathrm{SPACE}) + \frac{2}{\mathrm{T}}. \tag{24.4.2}$$

For example, in the Forward Link, $\nu(\mathrm{mark}) = 19$ MHz, $\nu(\mathrm{space}) = 17$ MHz and $t = 4$ microseconds (i.e. corresponding to a data rate of 250 kbps). Therefore, the bandwidth of the FSK signal in the forward link is

$$\Delta\nu = (19 - 17) + \frac{2}{4 \times 10^{-6}} = 2.5 \text{ MHz}. \tag{24.4.3}$$

24.5 System specifications of the Control & Monitor system

24.5.1 Overview

1. Non-coherent FSK is used for data transmission over the optical fiber links The baud rate is 250 Kbits/sec.
2. Bit interleaving is used for multiplexing the Telemetry, Voice, Sync., Dial and Aux channels.
3. Data integrity is checked using polynomial and checksum error detection with ARQ capability.
4. The Bit Error Probability is 10^{-10}.

24.5.2 Bit rates available for various services

	Service	Bit Rate (kbps)
1	DATA (COMH - ANTCOM COMM)	125.000
2	VOICE (TELEPHONY VOICE)	62.500
3	DIAL (TELEPHONY SIGNALING)	15.625
4	SYNC (SYNCHRONIZATION PATTERN)	15.625
5	AUX1 (AUXILIARY CHANNEL1)	15.625
6	AUX2 (AUXILIARY CHANNEL2)	15.625
	TOTAL BIT RATE	250.000

24.5.3 Details of the various communication links

Type	Subsystems	Involved		Rate
Ethernet	UNIX WS	<==>	PC ROUTER	10.0 Mbps
Asynchronous RS232-C 10 bit	PC ROUTER	<==>	COMH	38.4 kbps
SDLC/HDLC	COMH	<==>	ANTCOM	125 kbps
Asynchronous RS485 11 bit	ANTCOM	<==>	MCM	9.6 kbps
Asynchronous RS422 10 bit	ANTCOM	<==>	SCC	9.6 kbps
FSK MODEM	COMH	<==>	ANTCOM	250.0 kbps
VOICE	CEB	<==>	ANTENNA	62.5 kbps