A new SDH trunk radio system for 3 GHz – 13 GHz bands

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Abstract: An overview of the main features of the MDRS 155 EC radio system is presented. Special attention is given to the application of novel signal processing approaches and RF technology which permitted designing a transceiver unit with a very compact outline.

Keywords: adaptive filters, space diversity combiner, adaptive predistortion

1. INTRODUCTION

The MDRS 155 EC radio system has been designed as an indoor system for point to point long haul radio transmission. Large scale integration permits up to 10 STM-1 radio channels to be accommodated in a single ETSI or 19" rack. Applying new technologies such as LTCC for RF modules, new approaches to adaptive predistortion, space diversity combining and a *non-standard* way of system partitioning allowed to reduce footprint and overall power consumption significantly.

1.1 Main Features

The MDRS 155 EC radio system complies with the standards and recommendations of national and international organizations such as ETSI, ITU and CEPT. It is designed for the transmission of STM-1 signals (acc. to ITU-T Rec. G.707) at a bit rate of 155 Mbit/s per RF carrier. A radio link is always a repeater section (RST mode). Baseband interfaces can be either electrical (CMI) or optical. Supported optical types are S-1.1, L-1.1, L-1.2.

The system operates in the frequency bands ranging from 3 GHz to 13 GHz. Independent synthesisers for the transmitter and receiver allow for versatile adaptation to all channel frequencies and duplex spacings encountered in these frequency bands. Transmitter and receiver are integrated into a single unit which can be operated over the whole range of channel frequencies in a frequency band (e.g. tuning range about 1 GHz at 11 GHz band).

Supported system configurations:

(N+0) ; 2x(N+0)	(N ≤ 10)
(N+1) ; 2x(N+1)	(N ≤ 9)
1+1 HSB	(hot-standby)
1+1 line protection	(frequency diversity)

Some basic performance parameters such as TX power and receiver sensitivity are summarised in table 1.

Item	F-Band	128-QAM	64-QAM
	3.6...8 GHz	30 dBm	31 dBm
TX Power	11 GHz	29 dBm	30 dBm
@ A’	13 GHz	28 dBm	xxx
RX Level	3.6...8 GHz	-72 dBm	-73.5 dBm
(BER = 10^{-6})	11 GHz	-71.5 dBm	-73 dBm
@ A	13 GHz	-71.5 dBm	xxx

Table 1. TX power / RX sensitivity

A new approach to adaptive linearisation, integration of TX-/RX signal processing into a single ASIC and an additional integrated system controller (system on chip) leads to a significant reduction of power consumption .

Configuration	Power consumption
(1+0) terminal	80 W (max)
(10+0) terminal	800 W (max)

Table 2. Power consumption

The MDRS 155 EC radio system can be operated as a CCDP system with XPIC in all frequency bands.

1.2 System Components

The MDRS 155 EC radio system comprises a number of mandatory components. The range of possible applications can be extended by auxiliary modules. A short overview of mandatory system components is provided here.

Three basic system components constitute the core of the MDRS 155 EC radio system (see fig. 1):

1. Baseband unit (BBU)

2. Transceiver Unit (TRX unit)
3. Channel branching unit (CBU) including the antenna subsystem (feeder waveguide, antenna)

The BBU, which itself comprises a number of pluggable sub-modules, performs tasks such as SDH signal processing, radio protection switching, access to/from network management and local maintenance terminal.

The TRX unit implies modulation, TX signal processing, space diversity signal processing at the receiver, demodulation and handling of a reference signal from a cross-polar TRX unit in CCDP system configurations which require XPIC to eliminate cross-polar interference.

The channel branching unit (CBU) comprises two sub-units :

1. TX channel branching unit (CBU-TX)
2. RX channel branching unit (CBU-RX); in case of space diversity another RX channel branching unit (CBU-RXD) is required.

Each channel branching unit allows for *contiguous* multiplexing of RF channels (e.g. channel spacing 28 MHz). A branching circulator separates CBU-TX, CBU-RX.

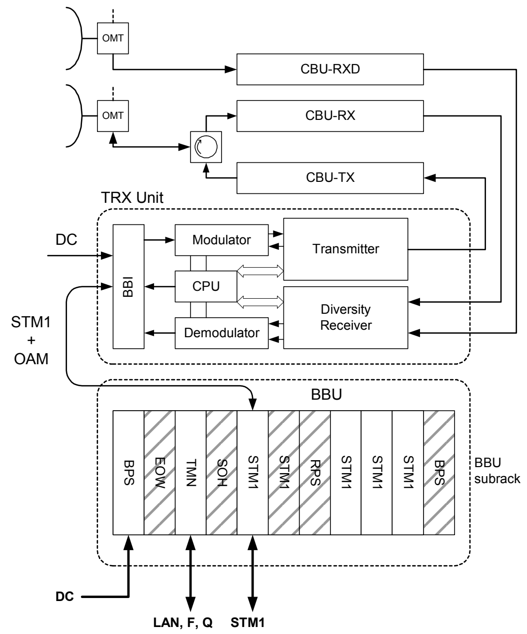

Fig. 1. Basic system components

1.3 Terminal Configurations

Terminal and repeater configurations are supported either unprotected or with radio protection switching (RPS). Unprotected configuration (N+0) with up to N = 10 channels and protected configurations (N+1) with up to N = 9 channels can be accommodated within a single ETSI or 19" rack.

2. BASEBAND UNIT (BBU)

All baseband signal processing functions not specific to the selected modulation format /128-/64-QAM are implemented by the BBU and its sub-modules. Moreover the modules / functions do not depend on the specific frequency band.

2.1 Overview

The BBU provides the following functions :

1. processing of electrical/optical STM-1 data streams (repeater section termination , RST)
2. radio protection switching of STM-1 data streams
3. insertion and extraction of service channels, EOW channels, wayside traffic, ECC channels, radio control channel information such as ATPC and RPS control signals
4. performance monitoring

In addition, the BBU provides the following interfaces:

1. interface(s) for connecting TRX units
2. access to a data communication network (DCN) for OAM functions
3. interface to a local maintenance terminal (LMT) for system configuration, software download, troubleshooting etc.

The BBU's modules are housed in a subrack. A common backplane provides interconnections between modules and interfaces. The following BBU modules are available:

1. STM1 module; up to 5 modules fit into one subrack (mandatory)
2. BPS module; up to 2 modules fit into one subrack (mandatory)
3. SOH module; one module may be accommodated by a subrack (optional)
4. RPS module; protection switching functions for line and equipment protection (optional)
5. TMN module; network management functions, system controller (mandatory)
6. EOW module; 64 kbps channel for voice transmission (optional)
7. ICC module (optional in conjunction with a second subrack for system expansion)

Up to 4 BBU's can be cascaded to accommodate up to 20 bidirectional STM1 channels which are managed by the TMN controller of the 1st BBU.

2.2 STM1 module

The STM-1 module performs the complete SDH processing for both the ingress / egress data streams of a radio channel. It provides a line interface for the STM-1 signal which can be either electrical or optical. In addition, this module covers central protection switching functions. Each STM-1 module supports all system configurations without any restrictions. The settings required for redundancy configurations (RPS, hot-standby) are software configurable via the local Operator Terminal PC (LMT). Signal processing blocks of the STM1 module are shown in fig. 2.

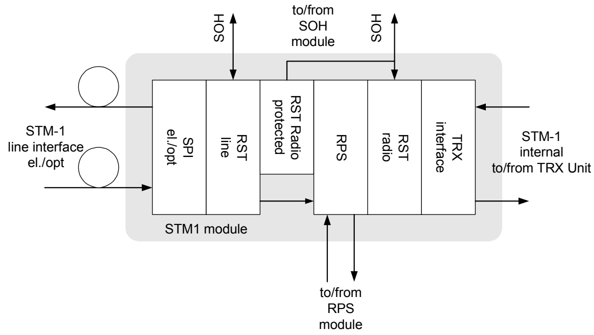

Fig. 2. STM1 module

In the "RST Line" and "RST Radio" blocks (RST Regenerator Section Termination), a complete processing of the regenerator section in the SOH takes place in compliance with ITU-T G.783 for both the line side and radio side. When necessary, the received STM-1 multi-frame (SOH) is passed on to the SOH module and the outgoing multi-frame is overwritten by the information supplied by the SOH module. In line protection or equipment protection configurations, the radio-side receive signal available behind the protection switching block is additionally taken into account. The line-side interface (SPI Synchronous Port Interface) is a pluggable SFP module.

On the transmit side, the RPS block branches the STM-1 signal from the line interface in the radio direction both to the TRX interface and in the RPS module direction. On the receive side, the exchange of STM-1 signals in the TX and RX direction and internal signalling data between the STM-1 module and TRX unit takes place via the TRX interface. STM-1 signals are transmitted as digital data and clock signals. For maximum switching speed, RPS communication required between STM-1 modules uses a dedicated CAN bus.

2.3 SOH module

The SOH module provides extraction / insertion capabilities of service-/wayside channels. Moreover it facilitates access to the data communication channels DCCr, DCCm used in a DCN. The following service channels are available:

1. E1 line side (64 kbps, G.703)
2. F1 line side (64 kbps, G.703)
3. E1 radio side (64 kbps, G.703)
4. F1 radio side (64 kbps, G.703)
5. DSC1-4 radio side (4x64 kbps, G.703)
6. Wayside channel WSC, radio side, (1x2 Mbit/s or 2x2 Mbps, G.703)

If the BBU subrack is equipped with 2 or more STM1 modules the SOH module can be configured to provide 1+1 protection of these service channels.

2.4 EOW module

In conjunction with the SOH module, the EOW module permits the E1 byte of the SOH to be used for voice transmission in the "STM-1 line" and "STM-1 radio“ directions. As third direction, an external EOW network can be connected either via a digital interface (64 kbit/s) or an analog 4-wire interface. The analog interface can also be used for interconnecting analog and digital service channel networks. Furthermore a PABX can be connected via an analog 2-wire line.

2.5 TMN module / ICC module

The main tasks of the TMN module include the connection of MDRS 155 EC radio system to a network management system and the provision of a local port for connecting an Operator Terminal PC. In addition, it provides user IO pins, i.e. eight signalling inputs and four signalling outputs that can be monitored and configured via the Network Management System (NMS). The Q-interface for network management connection is designed as LAN port (10 Mbps Ethernet) and located on the connecting panel. Another connector is available for the QD2 station bus (RS-485). In conjunction with the SOH module, further network elements can be connected to the Network Management System via the ECC in the "STM-1 radio“ and "STM-1 line" direction. For this purpose, either the DCCr (192 kbps) or DCCm (576 kbps) can be used.
All BBU subracks, without a TMN module mounted, must be equipped with an ICC module. The ICC module only provides a hub for the system-internal Ethernet connection between the central TMN module and TRX units.

2.6 RPS module

For line protection and equipment protection configurations, a RPS module is required in each subrack. It ensures the correct switching of signal paths between the N (N $\leq$ 9) operating channels and the protection channel and triggers the TX- side RF switch in equipment protection configurations. On the TX side, the traffic signals of all operating channels are branched in the respective STM-1 modules and passed on in parallel to the TRX units and RPS module available in the same subrack.

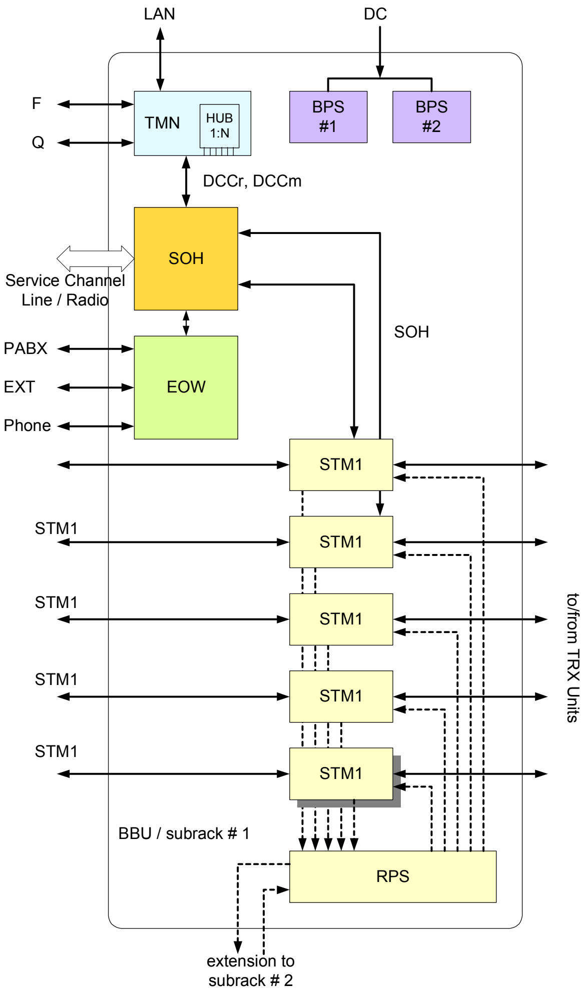

Fig. 3. BBU subrack equipped for (4+1) RPS

For enhanced reliability, protection switching communication with the far end radio system utilises all channels in parallel in a (N+1) system. A media-specific byte in the RSOH of the STM-1 signal outgoing in the radio direction is used as communication channel.

2.7 *BPS module*

The BPS module converts the potential free primary voltage (24-60V DC) applied via the connecting panel to the secondary voltages required by the BBU modules. A single BPS module supplies all modules available in a subrack. A second BPS module may be plugged into the BBU to provide redundancy in case of a failure.

3. TRANSCEIVER UNIT (TRX UNIT)

The TRX unit implements the TX-/RX-signal processing functions. Unlike many other radio systems, functionalities such as modulation, FEC, transmitter, receiver, synthesisers, demodulation (equalisation, space diversity combining, XPIC) are implemented into a single transceiver unit. The TRX unit is the only device which depends on the frequency band of operation. For the TX signal a novel approach to adaptive linearisation has been implemented. For the design of the receive section within the TRX unit we acknowledged that an increasing percentage of long haul radio links will employ space diversity reception to meet the required transmission quality. Hence the transceiver unit has been cost-optimised for space diversity operation.

3.1 *TX signal processing*

For the TX signal the STM1 signal is passed from the appropriate STM1 module of the BBU to the TRX unit's digital signal processor. The multilevel encoder maps the data signal to the configured QAM constellation 128-/64-QAM. Pulse shaping is performed by a programmable digital filter. An adaptive predistorter acts upon the digital I/Q signal components. The operating principle of the predistorter is based on adaptively weighting the envelope of the TX signal. Current predistortion weights are stored in a look-up table which is continuously updated. The pre-distorted I /Q signals are then converted to analogue signal which are used as input signals of the I-/Q upconverter. Upconversion is done directly to the configured TX channel frequency. A MMIC based high power amplifier (HPA) amplifies the QAM signal to its configured TX output level. A small part of the TX output signal is downconverted to an intermediate frequency. The IF signal is then sampled by an ADC and passed back to the signal processing ASIC. Using this feedback signal it is possible to detect nonlinear distortion from the I/Q upconverter and the HPA by comparison with the internal signal prior to predistortion (fig. 4). Moreover it is possible to identify imperfections such as I/Q imbalance, quad-error and LO feedthrough and compensate for them adaptively.
A system on chip performs time critical tasks such as

1. calculation of new entries of the look-up table storing the predistorter weights
2. ATPC, TX power control
3. automatic gain control of the receiver
4. adjustment of biasing currents of the HPA

The adaptive predistorter tracks fast changes of the HPA nonlinearity typically encountered in radio systems when ATPC has been enabled. The novel approach to predistortion no longer requires well-behaved AM/AM-, AM/PM nonlinearities of the HPA that may be modelled by low order polynomials. It permits operation of the TX high power amplifier with TX peak power values close to the amplifier's 3 dB saturation point. Thus linearisation gains obtained exceed performance of conventional polynomial predistorters by far. Moreover design constraints on the HPA could be eased significantly and power consumption of the TRX unit was drastically reduced. Fig. 5 shows that typical linearisation gains exceed 20 dB and frequency efficient transmission is feasible due to much reduced out-of-band emissions.

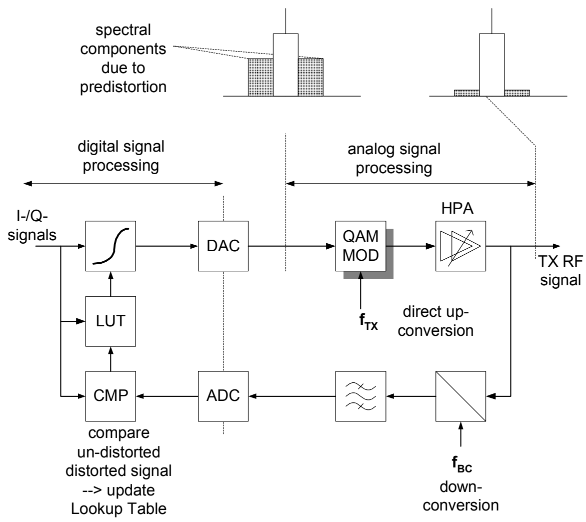

Fig. 4. digital adaptive lineariser using internal feedback channel

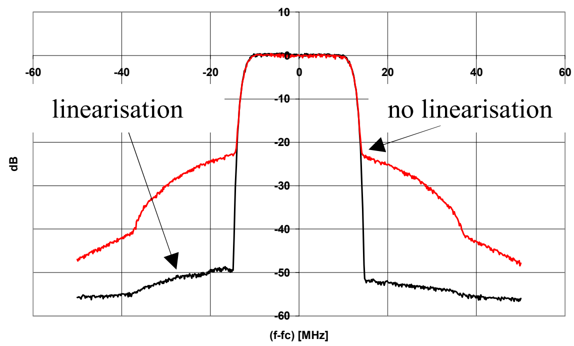

Fig. 5. Improvement of TX spectrum w/o adaptive linearization

Fig. 6 shows the very compact design of the RF module which comprises all RF processing functions for the TX-, RX-signals.

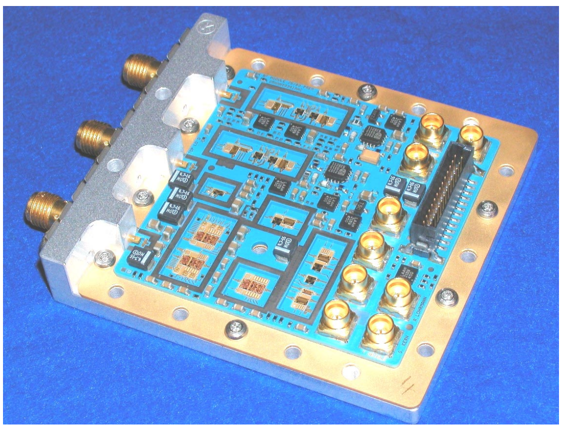

Fig. 6. RF Module on LTCC substrate

3.2 *RX signal processing*

Opting for a receiver optimised for space diversity operation led to the implementation of a twin-receiver within a single TRX unit. Thus a dedicated diversity receiver has become obsolete.

Main and diversity signals are received via two low-noise amplifiers / down-converters. The heterodyne receiver uses a 1^{st} IF of 1400 MHz and a 2^{nd} IF of 140 MHz.

If the microwave radio system operates in the CCDP mode, a copy of the received signal must be passed to the other TRX unit which processes the appropriate cross-polar signal. This signal will be referred to as XPIC signal in the following. XPIC signals between cross-polar TRX units are exchanged via the XPIC interface using coaxial cables.

The main and diversity signals as well as the XPIC signal are converted to digital signals by sampling the signals at the 2^{nd} IF frequency with a sampling rate of about 186 Msmps. Direct sampling of the received signals at the 2^{nd} IF frequency no longer requires dedicated QAM demodulators for IF to baseband conversion thus leading to a very compact design of the TRX unit.

Sampled Main-, Diversity-, XPIC-signals are passed to the digital signal processing ASIC. After sampling rate conversion to twice the symbol rate, 3 adaptive slope equalisers compensate for attenuation slopes in the Main-, Diversity-, XPIC-signals. 3 programmable digital filters perform pulse shaping of the received signals, suppress adjacent channel interference etc…

A novel digital signal processing architecture achieves adaptive equalisation, diversity combining and cross-polar interference cancellation using 3 T/2 spaced adaptive equalisers and a decision feedback equaliser. Delay compensation of diversity signals is a fully automated procedure. It is an integral part of the implemented signal processing and therefore does not require additional hardware. Finally error correction decoding is performed by the multistage decoder (2 Viterbi decoders, 1 SPC decoder). The regenerated data stream is passed to the appropriate STM1 module of the TRX unit.

4. CHANNEL BRANCHING UNIT (CBU)

The channel branching unit comprises a TX channel branching unit and an RX channel branching network interconnected by a circulator. Each channel branching network has RF channel filters connected to a branching circulator. In case of a space diversity system, another channel branching network for the RX diversity channels is required. The antenna waveguide is connected via a flexible coaxial cable with waveguide transition (PDR flange) to the channel branching unit. It is possible to connect diplexer filters to the circulators of the branching unit. Use of optional multiple diplexer-filters permit a low-loss branching network to be set up.

5. OPERATION AND MAINTENANCE

Management of the MDRS 155 EC radio system is possible either locally or remotely. The local maintenance terminal (LMT) is a PC based application for system commissioning and maintenance. Initial setup of a network element is done with the LMT. Various connection options are provided:

1. locally via serial interface (RS-232)
2. locally via TCP/IP
3. remotely via TCP/IP or OSI
4. remotely using a modem connected to the RS-232 interface of the BBU.

Control and monitoring tasks can be invoked from the LMT as in service operations (traffic not affected). Persistent data such as

1. configuration data specific to modules / sub-systems
2. identifiers of modules / sub-systems

are stored on the modules. The TMN module maintains collections of performance data.

5.1 Network management

Remote login to a distant MDRS 155 EC radio system is also possible via the *ServiceOn Access* (SOA) network management system. Communication networks establishing the interconnection between the radio system and the SOA NMS may use one of the following interconnection types:

1. QD2 DCN
2. OSI-DCN
3. IP-DCN

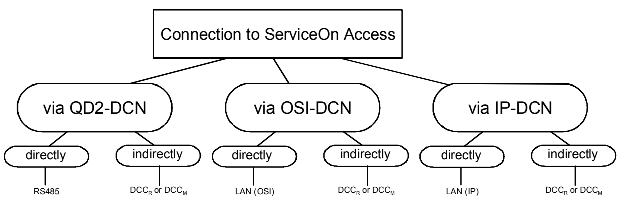

Fig. 7. Connection options to NMS ServiceOnAccess (SOA)

Exchange of management information over these networks is based on the SISA protocol (**S**upervisory and **I**nformation **S**ystem for local and remote **A**reas). DCN routing is implemented for OSI and IP networks. The router is implemented in the TMN module of the BBU. Several routing protocols are implemented:

1. OSI routing (ES-IS, IS-IS L1, IS-IS L2)
2. IP routing (static and OSPF)

Network management via SNMP is a feature in preparation.

5.2 Software Management

The Marconi LH digital microwave radio system is composed of eight software modules/sub-systems:

1. TMN module
2. STM-1 module
3. SOH module
4. RPS module
5. EOW module
6. BPS module
7. ICC module
8. TRX unit (Transceiver)

Distribution of software is done via the TMN module as shown in figure 8.

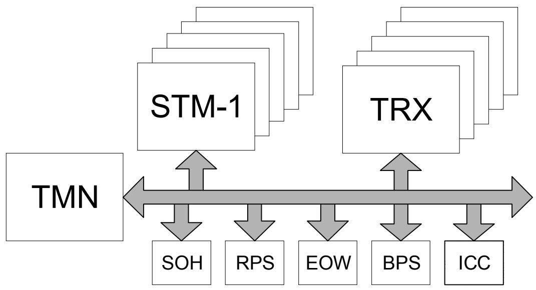

Fig. 8. Software modules

The individual software parts of each module/sub-system are combined into a software package or system release. The software of a system release/software package is downloaded to the network element via the DCN. A verification step ensures that the download has been successful. Downloading a new system release does not affect system operation. It is accomplished as a background process. To become effective the downloaded software must be activated by entering the appropriate command. A subsequent verification step checks whether activation has been successful. The switch-over to a new system release does not affect or interrupt traffic.

The software architecture supports full plug & play functionality. Replacement of modules leads to an automatic reconfiguration of the newly plugged in module since all configuration data are stored in the TMN module. Therefore field replacement of defective modules is possible without reconfiguration via LMT.

5.3 Performance monitoring

Monitoring of general performance parameters is in accordance with ITU-T G.826 / G.828.
Moreover the performance monitoring includes all radio specific performance parameters described in EN 301 129 and ITU-R F.750-4.

6. BUILT IN TESTS / FAULT MANAGEMENT

The STM1 modules of the BBU provide several configurable test loops in direction line and radio (TRX Unit).
Similarly the TRX unit offers loopback facilities at baseband level in direction line and radio and an additional RF loopback for the TX output signal of the HPA. The signal processing ASIC of the TRX unit provides test signals such as CW, 2-tone, M-tone which are helpful during manufacturing and test. An internal data generator and a device for bit error rate measurements can be used in system and production tests without the necessity of an external BER tester.

CONCLUSION

The new MDRS 155 EC trunk radio system operates in frequency bands 3 GHz to 13 GHz. It employs a quite unique approach to partition the signal processing functions. All functionalities which depend on modulation and frequency band have been integrated into a transceiver unit. Using a powerful, feedback controlled adaptive predistorter, a dual receiver optimised for space diversity reception and RF technology such a LTCC lead to a very compact transceiver. Moreover the new radio design led to a reduced power consumption of only 80 W per STM1 channel. Baseband processing functions such as STM1 processing, radio protection switching and access to service channels are implemented by modules of the baseband unit (BBU). The compact design of BBU and transceiver units permits to accommodate up to 10 STM1 channels in a single ETSI of 19” rack. For optimum use of channel frequencies, CCDP operation with XPIC is possible in all frequency bands.

ABBREVIATIONS

ATPC	automatic transmit power control
CCDP	co-channel dual polarised
DCN	data communication channel
ECC	embedded communication channel
EOW	engineering orderwire
LTCC	low temperature co-fired ceramic
RPS	radio protection switching
RST	repeater section termination
SOH	section overhead
TRX	transceiver
XPIC	cross polar interference canceller

BIOGRAPHY

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