SPECTRAL EFFICIENCY OF COMMERCIAL WIRELESS AND TELEMETRY SYSTEMS IS DOUBLED WITH IRIG 106-00 STANDARDIZED FQPSK AND IS QUADRUPLED WITH FQAM

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ABSTRACT

Advances in spectrally efficient Feher's Quadrature Phase Shift Keying (FQPSK)[1] and Feher's Quadrature Amplitude Modulation (FQAM)[1] patented technologies, commercial and government "dual-use" FQPSK products and Test & Evaluation (T&E) results are highlighted in this overview paper. US and international customer requirements/systems, programs and recent deployments and standardization programs are also described. FQPSK doubles the spectral efficiency of PCM/FM Telemetry and of Feher patented Gaussian Minimum Shift Keying (GMSK or FGMSK)[1] and of alternatives, while FQAM quadruples the spectral efficiency of these systems. The predominant focus of this presentation is on an overview and advances of IRIG 106-00 standardized FQPSK technologies. FQAM systems will also be described. Use of FQPSK for applications such as telemetry, data links, clear mode, TDMA ,CSMA and CDMA, OCDMA, WCDMA as well as OFDM – COFDM will be included in the presentation.

KEYWORDS

Feher's patented Quadrature Phase Shift Keying (FQPSK); Feher's patented Gaussian Minimum Shift Keying (FGMSK); Feher's patented Quadrature Amplitude Modulation (FQAM); Gaussian Minimum Shift Keying; Spectral Efficient; Bandwidth Efficient.

File: ITC 00 FQPSK Feher's Paper Proc. International Telemetry Conference ITC/USA 2000 San Diego

1. INTRODUCTION

Numerous Government and Commercial "dual-use" systems/programs have requirements for spectrally efficient telemetry systems, data links and other spectrally efficient wireless and broadcasting very high bit rate-high speed applications. Several programs specified the use of Feher's patented Quadrature Phase Shift Keying FQPSK[1]. U.S. Department of Defense (DoD), NASA, AIAA, and International CCSDS multiyear studies confirmed that FQPSK commercially available products offer the most spectrally efficient robust/best performance Non Linearly Amplified (NLA) high speed and also "Ultra High Bit Rate (up to 1Gbit/s) Bandwidth/RF power Efficient Solutions. The AIAA 1998 approved standard recommended to the U.S. Department of Defense (DoD), NASA and the International CCSDS that FQPSK modulation be standardized.

For bit rate agile RF power/spectral efficient, high performance ULTRA HIGH BIT RATE (up to 1Gb/s rate) applications cost efficient FQPSK developments, implementations and tests are described in NASA co-authored papers. See listed references. Forward/Backward Interoperability of IRIG-106-00 Standardized FQPSK-B with 3G Commercial Wireless Systems, with GSM, with commercial TDMA, with Government Operated Legacy Data Links and with 3G [3rd Generation] CDMA commercial systems are also discussed.

The recently issued Telemetry Standard IRIG 106-00
[See: www.http://tecnet0.jcte.jcs.mil/RCC/manuals/106-00/] specified for higher bit rate better bandwidth efficiency telemetry systems the use of FQPSK-B. Numerous Government and Commercial systems/programs have requirements for spectrally efficient telemetry systems, data links and other spectrally efficient wireless and broadcasting very high bit rate applications. Several programs specified the use of FQPSK. For bit rate agile RF power/spectral efficient, high performance ULTRA HIGH BIT RATE (up to 1Gb/s rate) applications cost efficient FQPSK developments, implementations and tests are described in NASA co-authored papers. Forward/Backward Interoperability of IRIG-106-00 Standardized FQPSK-B with 3G Commercial Wireless Systems, with GSM, with commercial TDMA, with Government Operated Legacy Data Links and with 3G [3rd Generation] CDMA commercial systems are also discussed.

Recent R&D achievements and study results, reported in this contribution demonstrate that enhanced performance Feher patented FQPSK[1] systems have a 1dB improved BEP performance as compared to that of inter-operable and fully compatible IRIG 106-00 standardized FQPSK-B bit rate agile 1Mb/s to 20Mb/s range transmitters and receivers.

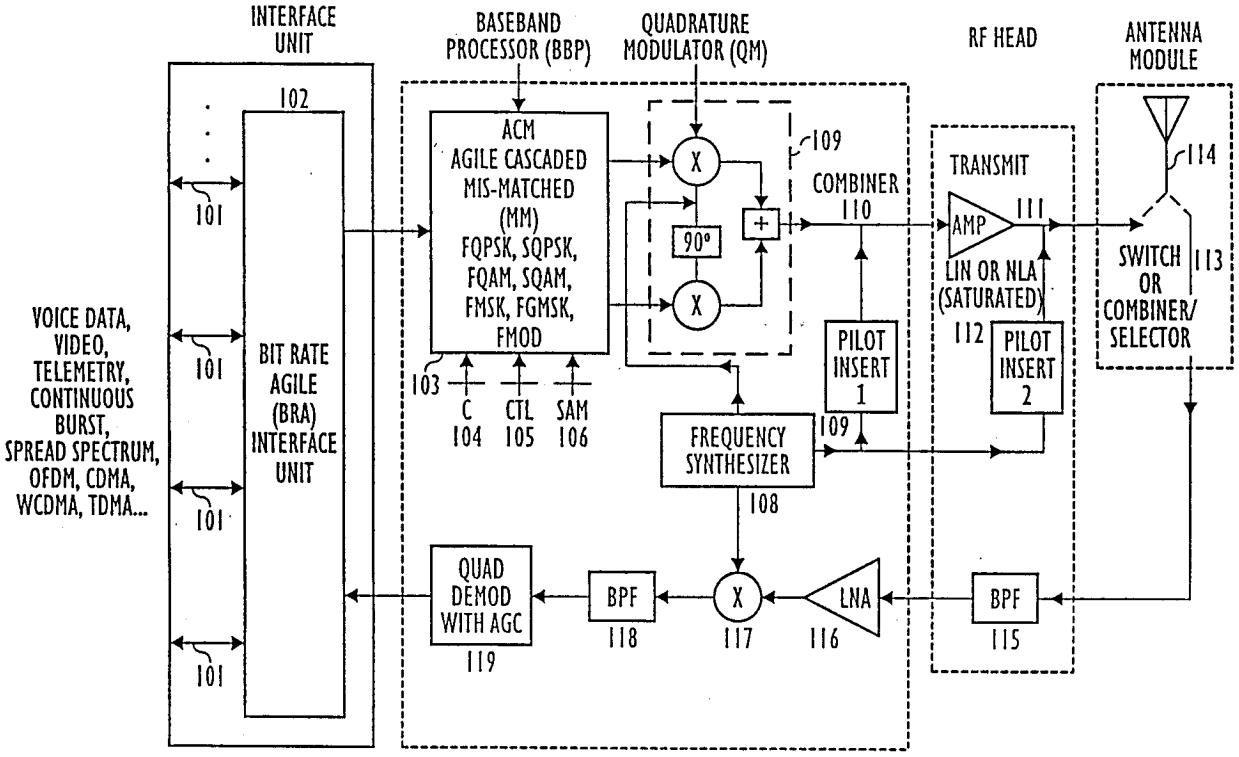

Fig. 1 A generic implementation of Feher patented GMSK, FQPSK, SQPSK, FQAM, SQAM, FMSK, FGMSK, and FMOD transmitter and receiver is illustrated; drawing is based on one of Feher's International patent publications – PCT contained in Ref. [1]

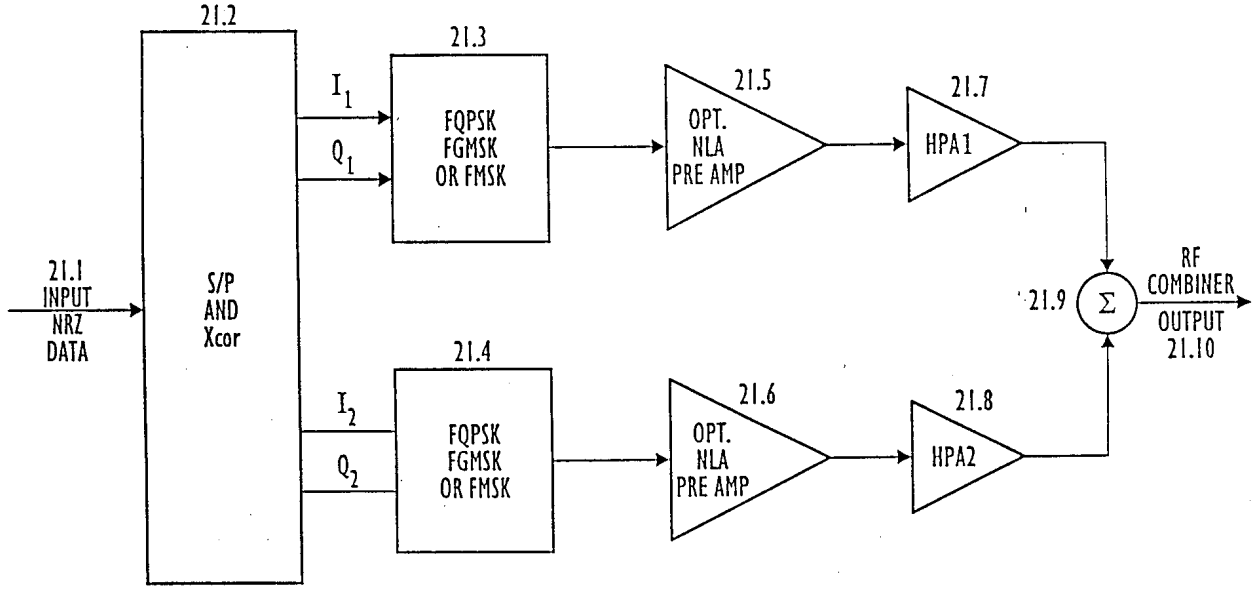

Fig.2 A Non linearly Amplified (NLA) architecture of Feher patented QPSK and GMSK including FQPSK, FGMSK, FMSK and FQAM having 16 states is illustrated [1].

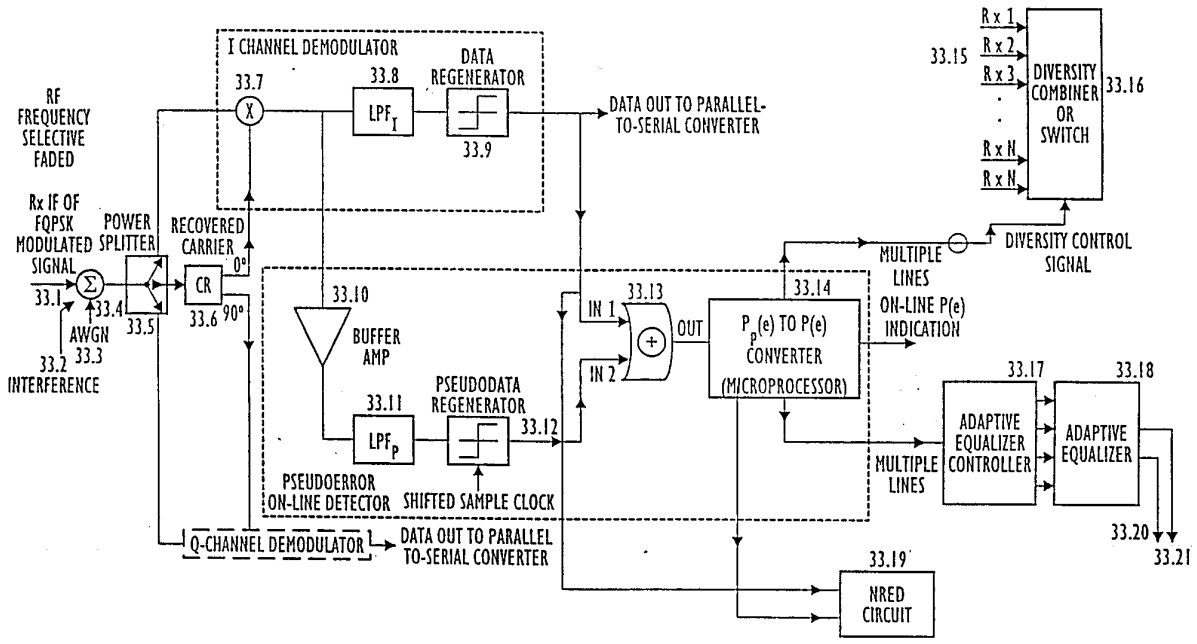

Fig. 3 An adaptive Feher Equalizer (FE) based implementation with pseudo error non-redundant error detection or non-redundant error correction is depicted; based on [1].

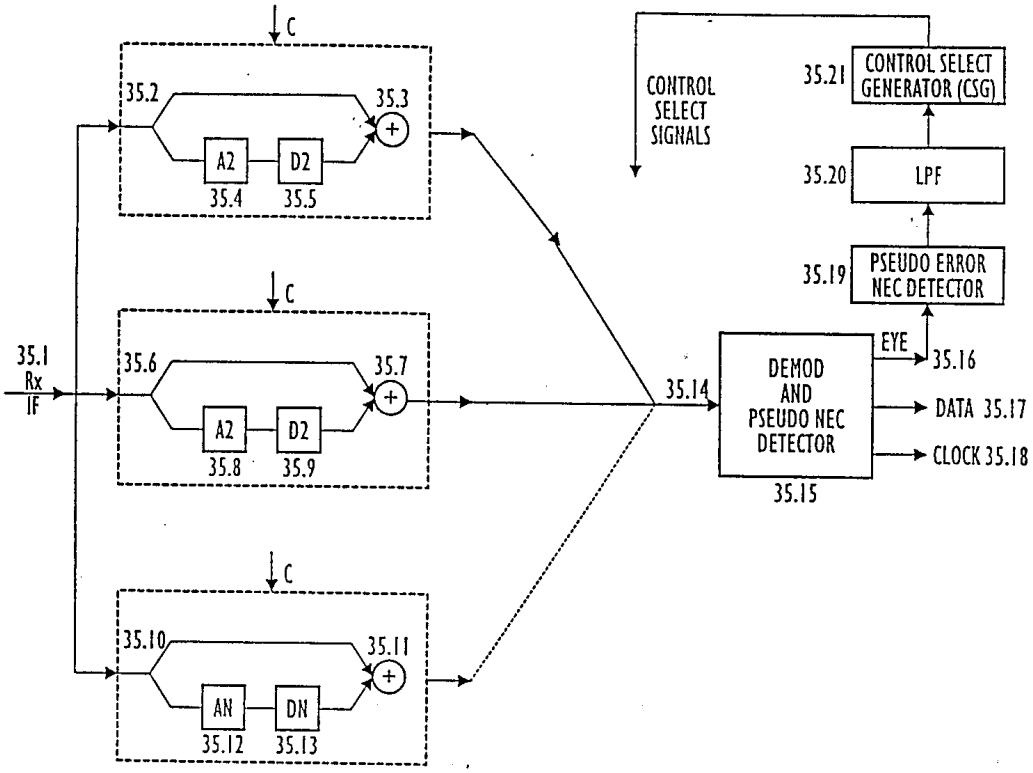

Fig. 4 An implementation architecture of a Feher patented pseudo error - adaptive equalizer – diversity combiner taken from [1] is illustrated.

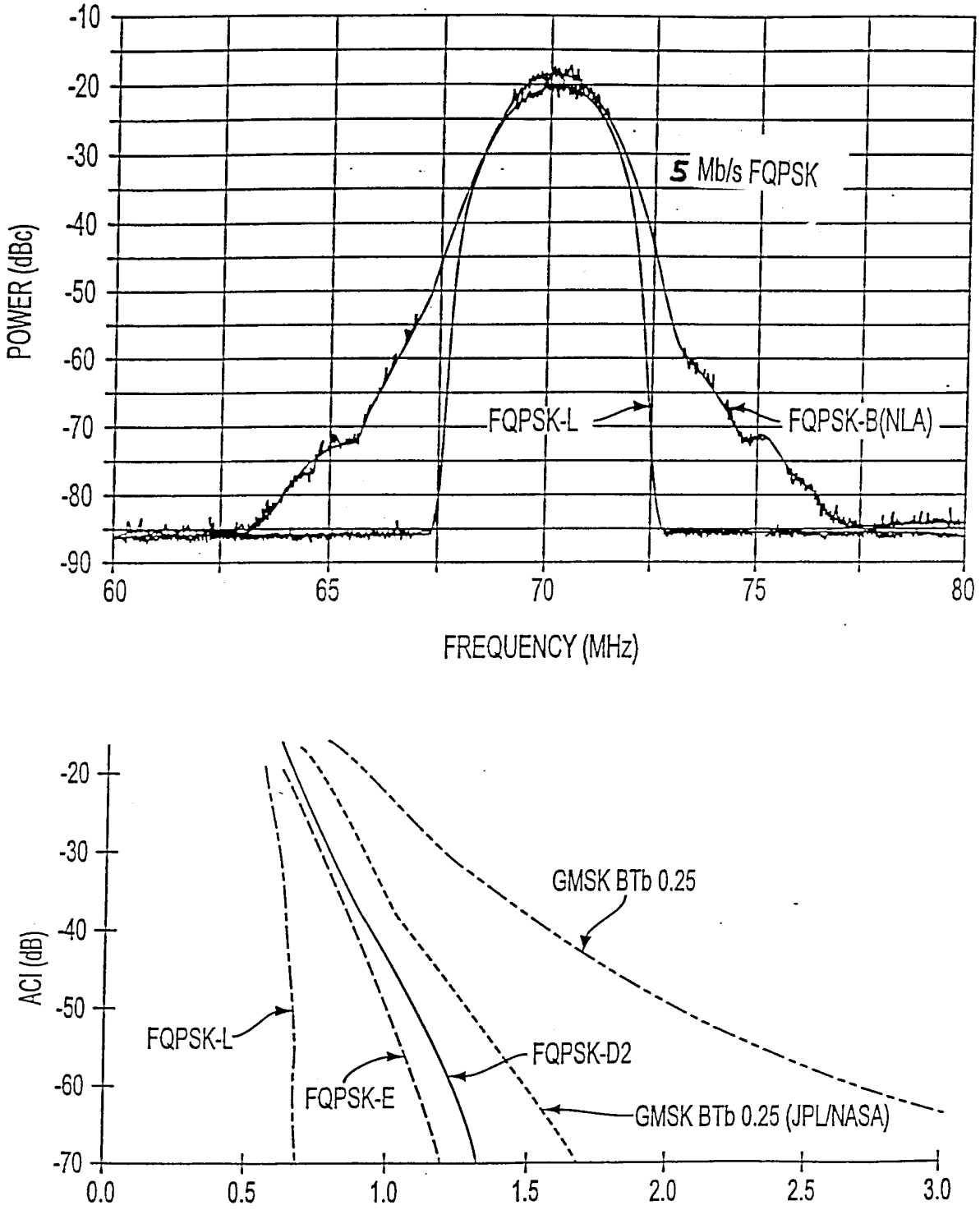

Fig. 5 and Fig. 6 In the upper figure a nonlinearly amplified FQPSK-B spectrum and an FQPSK-L spectrum (with approx. 3dB output backoff) is shown. In the lower figure integrated Adjacent Channel Interference (ACI) of several Feher patented GMSK and FQPSK systems is shown.

Adaptively equalized FQPSK systems, with ultra fast dynamic adaptive Feher Equalizers (FE) [1] are also discussed. Progress in non-redundant Error Detection (Pseudo-Error) based controlled Adaptively Equalized and SMART antenna-diversity multiple array FQPSK systems is also presented[1]. Low redundancy (5% to 10% range) Forward Error Correction (FEC) combined with FQPSK is demonstrated to lead to an approximately 5dB increase in the data link margin.

An overview of several FQPSK based programs operated and implemented in the 100kb/s to 40Mb/s range and implementations in the ultra high bit rate, up to 600Mb/s range are also presented.

Forward/Backward Interoperability of IRIG-106-00 Standardized FQPSK with 3G Commercial Wireless Systems, GSM, Government Operated Legacy Data Links and Wideband W-CDMA is briefly described.

Presentations in this FQPSK Forum, held during the ITC/USA 2000, San Diego CA conference, include aeronautical telemetry flight tested FQPSK-B products which DOUBLE the Spectral Efficiency of PCM/FM Telemetry, of Feher patented GMSK and of other Non Linearly Amplified (NLA) power efficient alternatives. Most recent developments, including FQPSK performance optimization achievements and developments of 2nd Generation FQPSK, also designated as Feher patented FQAM, which QUADRUPLE the spectral efficiency of presently deployed PCM/FM telemetry systems are also described .

2. INTERNATIONAL CCSDS SPECTRALLY EFFICIENT STANDARDIZATION DEVELOPMENTS

For International CCSDS standardization, in Ref [32] NASA/JPL recommended that FQPSK-B to be selected as the CCSDS recommended standard because:

1. Reference 11 (in [32]) showed FQPSK-B's bandwidth efficiency to be better than that of GMSK.
2. Reference 12 (in [32]) showed acceptable FQPSK-B end-to-end losses and interference susceptibility.
3. FQPSK-B hardware mechanization is considerably simpler than that for GMSK.
4. FQPSK-B hardware tests are showing it can support a full range of data rates
   a) Data rates from a few bits/second to 300 Mb/s. b) Real hardware exists.
5. FQPSK-B patent issues appear to be substantially simpler than those for GMSK.
6. Digcom has agreed with License Agreement changes requested by space Agencies.

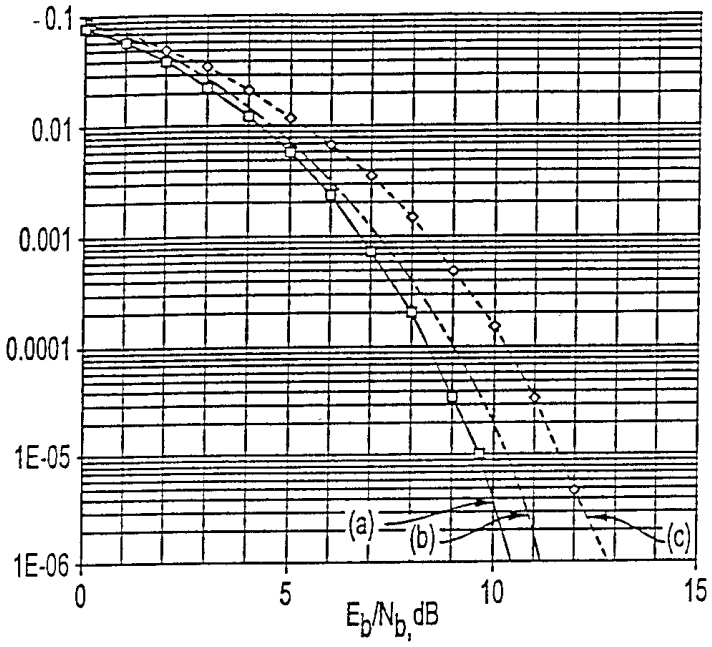

Fig. 7 Bit Error Rate (BER) performance of nonlinearly amplified FQPSK and of ideal theoretical linearly amplified QPSK is illustrated. Curve (a) is the ideal theoretical linearly amplified QPSK performance; (c) illustrates a very simple NLA operated FQPSK-B system and (b) illustrates an enhanced perfor. FQPSK-B [1; 14; 39;47 48].

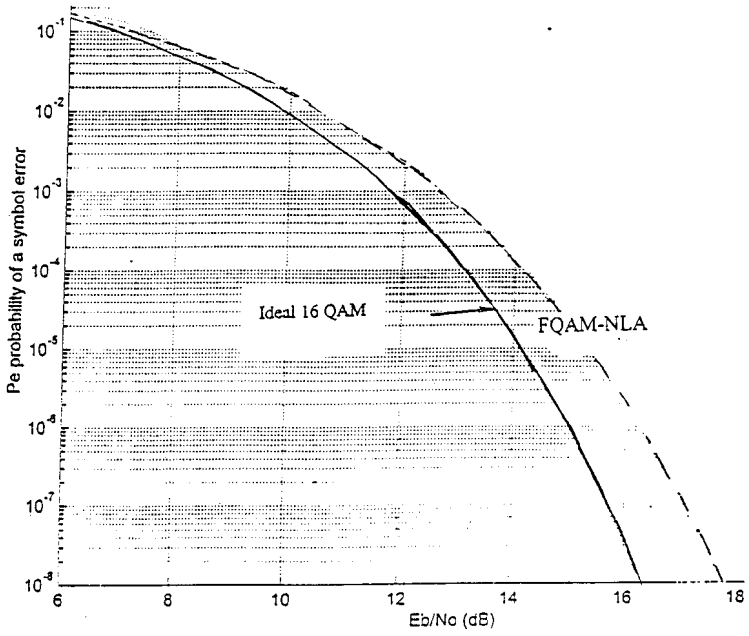

Fig. 8 BER performance of Feher's FQAM patented systems (16 state FQAM which quadruples spectral efficiency of PCM/FM and is illustrated in Fig. 2) and of ideal theoretical linearly amplified 16-QAM [1].

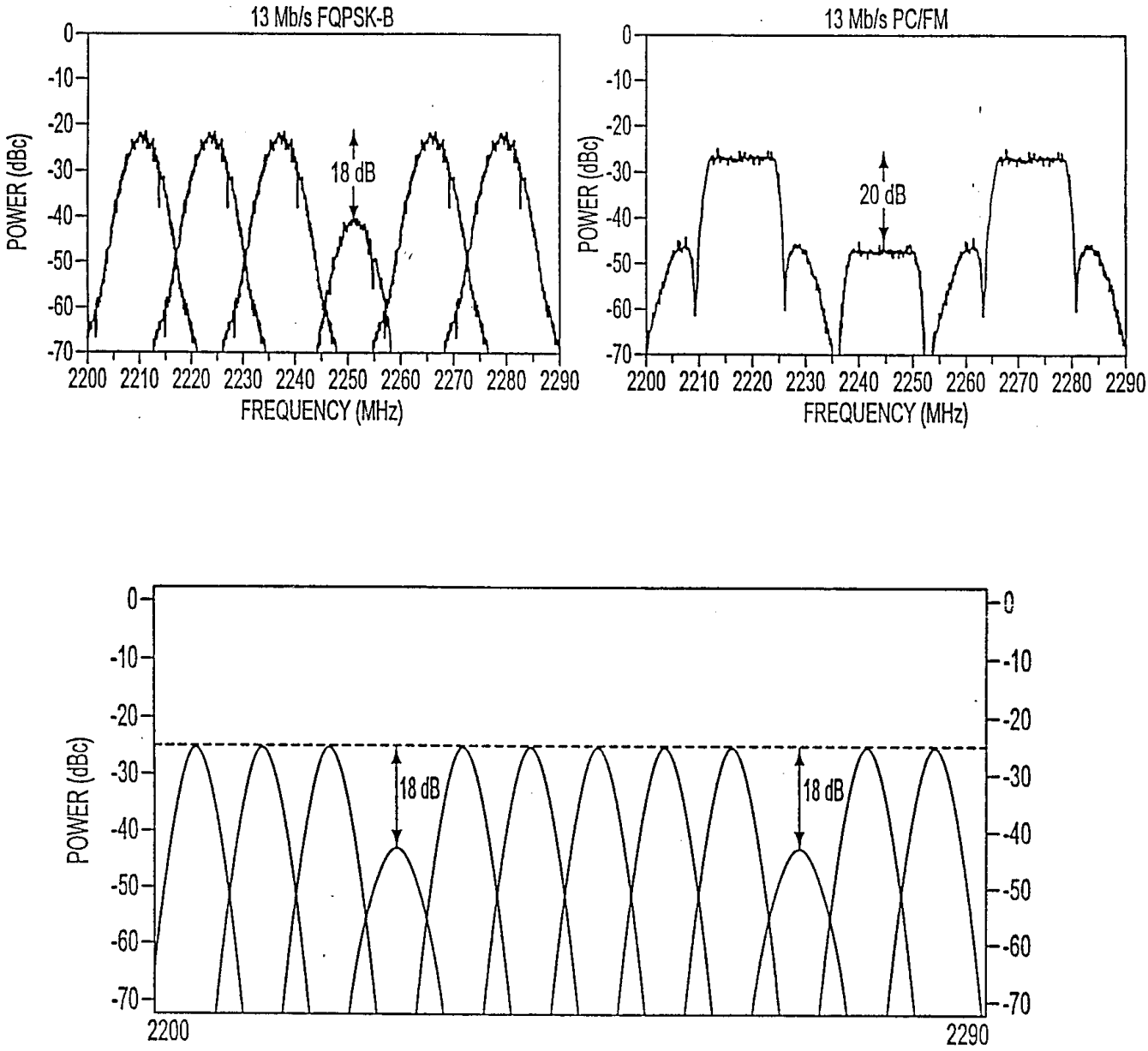

Fig. 9 The spectral efficiency advantages of FQPSK and 16-state FQAM over that of PCM/FM are illustrated [1]. In the illustrated S-band 3 PCM/FM 13Mb/s channels or 6 FQPSK-B 13Mb/s channels or 12 FQAM-NLA 13Mb/s channels can be transmitted. FQPSK doubles, enhanced FQPSK triples, and NLA FQAM quadruples the spectral efficiency of previously standardized PCM/FM systems.

TABLE 1. List of Feher patented FQPSK and Feher patented GMSK licensees, manufacturing companies & cooperating US Department of Defense (DoD), NASA, AIAA, International CCSDS programs/customers and member organizations of the FQPSK Consortium (1995- 2000):

L3 Communications, Inc:	Telemetry East-Aydin	Conic
	Interstate Electronics Co. (IEC)	Microdyne
Lockheed Martin	RF Networks, Inc.	Herley Industries-Vega
Tasc – Litton	Tybrin	EIP Microwave
Iota/NeoSoft	Emhiser Research Inc.	Applied Signal Tech.
	Broadcast Microwave Syst.	INTEL Corporation
	Semco	Centraxx
US DoD:	SBIR(US Air Force)	ARTM-US Air Force -Edwards
CRADA	US Navy China Lake and	CRADA-U.S. Navy -Pt. Mugu
FIRST; FIT	TGRS	Telemetry RCC
NASA:	TCA w/JPL-NASA	
		300Mb/s - 600Mb/s FQPSK
		NASA: Goddard and NASA/JPL
Standardization: AIAA	CCSDS; SFCG; ESA	FIT; Telemetry IRIG 106-00
Universities:	NMSU	University of California ,Davis
	Calif. Institute of Technology (CalTech)	

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