The Consultative Committee for Space Data Systems

Draft Recommendations for Space Data System Standards

RADIO FREQUENCY AND MODULATION SYSTEMS—

PART 1
EARTH STATIONS AND SPACECRAFT

DRAFT RECOMMENDED STANDARD

CCSDS 401.0-P-15.1

PINK SHEETS

August 2005

2.4.11 PHASE-AMBIGUITY RESOLUTION FOR QPSK/OQPSK MODULATION SYSTEMS USING A SINGLE DATA SOURCE [1]

The CCSDS,

considering

(a) that resolution of phase ambiguities in the earth station's receiver is an inherent problem with systems using coherent Quaternary Phase-Shift-Keying (QPSK) and Offset QPSK (OQPSK) modulation;

(b) that ~~coding~~ bit mapping conventions for QPSK systems are unambiguously defined in CCSDS Recommendation 401 (2.4.10);

(c) that the phase ambiguity results from ~~an inability of~~ the lack of transmission of reference phase information, thus making it impossible for the receiver's carrier recovery circuitry to select the correct reference phase from the four possible stable lock points (Table 2.4.11-1);

(d) that when convolutional encoding is used, some Agencies perform node synchronization based on the encoded frame synchronization marker before the convolutional decoder, while some Agencies use the metric growth in the convolutional decoder;

(~~d~~e) that the phase-ambiguity can be resolved by using the techniques listed in Figure 2.4.11-1;

(~~e~~f) that the several methods for resolving the phase ambiguity depicted in Figure 2.4.11-1 are evaluated in Table 2.4.11-2;

(~~f~~g) that most space agencies currently employ differential ~~encoding~~ data formatting and synchronization (sync) markers for framed data transmission;

(~~g~~h) that any of the four possible phase states result in an unambiguously identifiable unique word pattern according to Table 2.4.11-1 which can be used to resolve the phase ambiguity;

(~~h~~i) that the sync markers already existing in the framed data transmission can be used as the unique words for resolving the phase ambiguity;

(j) that even though a single convolutional encoder can be used prior to the I/Q split in the transmitter, there is a penalty (in terms of higher E_b/N_0) to allowing the single decoder to resolve the phase ambiguity;

recommends

(1) ~~that the sync marker(s), if available,~~ that, if the capability exists in the ground stations, sync marker(s) shall be used to resolve the phase ambiguity;

NOTE:

1. **Such systems employ a single, serial data stream and the ~~channel~~ bit mapping ambiguity is resolved in accordance with CCSDS Recommendation 401 (2.4.10) B-1.**

2.4.11 PHASE-AMBIGUITY RESOLUTION FOR QPSK/OQPSK MODULATION SYSTEMS USING A SINGLE DATA SOURCE (Continued)

(2) that when sync marker(s) are used with coded systems, the synchronization shall be performed prior to convolutional decoding;

(~~2~~3) that the differential ~~encoding~~ data formatting techniques defined in CCSDS Recommendation 401 (2.4.2) shall be used when ~~no~~ the sync marker is ~~available~~not used~~.~~;

(4) that when differential data formatting is used with coded systems, the I and Q channels shall be encoded (and therefore decoded) independently with the differential data formatting performed prior to convolutional encoding.

2.4.11 PHASE-AMBIGUITY RESOLUTION FOR QPSK/OQPSK MODULATION SYSTEMS USING A SINGLE DATA SOURCE (Continued)

ANNEX TO RECOMMENDATION

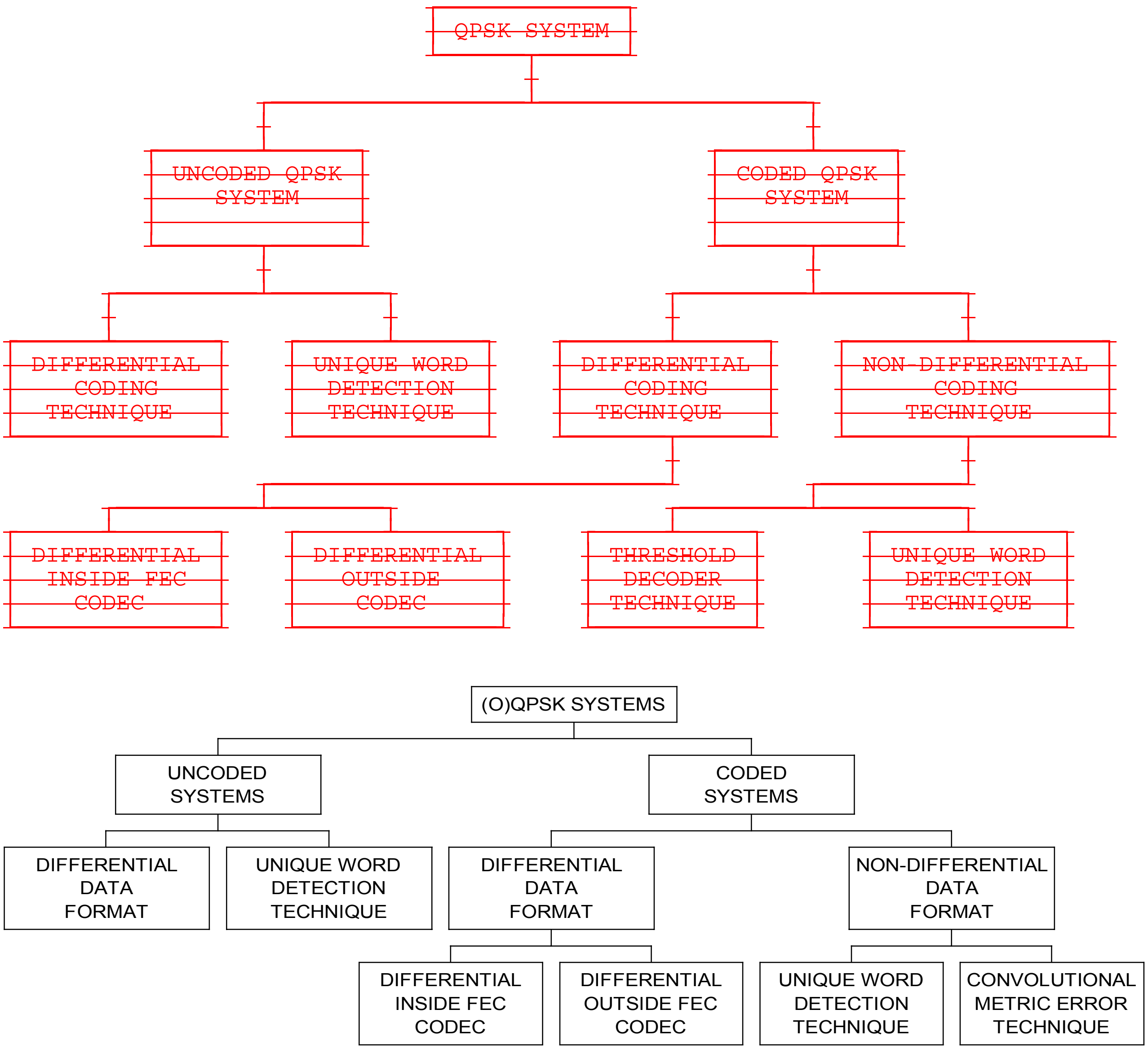

FIGURE 2.4.11-1: LIST OF PHASE-AMBIGUITY RESOLUTION TECHNIQUES

LEGEND:

FEC : Forward-Error-Correct~~ing~~ion
CODEC: Encoder and Decoder Pair

2.4.11 PHASE-AMBIGUITY RESOLUTION FOR QPSK/OQPSK MODULATION SYSTEMS USING A SINGLE DATA SOURCE (Continued)

ANNEX TO RECOMMENDATION (Continued)

TABLE 2.4.11-1: RELATIONSHIPS BETWEEN THE TRANSMITTED AND RECEIVED DATA

CARRIER PHASE ERROR (DEGREES)	RECEIVED DATA I_R	Q_R
0	I_T	Q_T
90	$-Q_T$	I_T
180	$-I_T$	$-Q_T$
270	Q_T	$-I_T$

NOTE:

1. **The negative sign indicates the complement of the data.**

2.4.11 PHASE-AMBIGUITY RESOLUTION FOR QPSK/OQPSK MODULATION SYSTEMS USING A SINGLE DATA SOURCE (Continued)

ANNEX TO RECOMMENDATION (Continued)

TABLE 2.4.11-2: SUMMARY OF THE SALIENT FEATURES OF ~~THE PREFERRED~~AVAILABLE TECHNIQUES

~~PREFERRED~~AVAILABLE TECHNIQUES	BIT ERROR RATE (BER) DEGRADATION	ADVANTAGES & DISADVANTAGE
UNIQUE WORD DETECTION	~~NEGLIGIBLE~~NONE	~~- REQUIRES UNIQUE WORDS~~ - INCREASE EARTH STATION COMPLEXITY ~~- INCREASE BANDWIDTH~~
DIFFERENTIAL ~~CODING~~ DATA FORMATTING WITHOUT FORWARD-ERROR-CORRECT~~ING~~ION (FEC)	INCREASES BY APPROXIMATELY A FACTOR OF TWO	- SIMPLE TO IMPLEMENT - CAN CAUSE DEGRADATION IN THE DETECTION OF THE TRANSMITTED SYNC MARKERS
DIFFERENTIAL ~~CODING~~ DATA FORMATTING INSIDE THE FEC ENCODER AND DECODER PAIR (CODEC)	~~BIT SNR DEGRADATION IS~~ ABOUT 3 dB FOR CONVOLUTIONAL CODE WITH R = ½, K = 7	- PROVIDES QUICK PHASE AMBIGUITY RESOLUTION - REQUIRES OVERPOWERED LINK
DIFFERENTIAL ~~CODING~~ DATA FORMATTING OUTSIDE THE FEC CODEC	~~NEGLIGIBLE~~SMALL	- REQUIRES ~~RELATIVELY LONG TIME TO RESOLVE THE PHASE AMBIGUITY~~DIFFERENTIAL DECODERS AT THE STATION
~~THRESHOLD DECODER~~	~~NEGLIGIBLE~~	~~- REQUIRES LESS BANDWIDTH~~ ~~- REQUIRES RELATIVELY LONG TIME TO RESOLVE THE PHASE AMBIGUITY~~ ~~- DOES NOT PROVIDE AS MUCH CODING GAIN AS VITERBI AND SEQUENTIAL DECODERS~~

2.5.1B MINIMUM EARTH STATION GROUP DELAY CALIBRATION ACCURACY, CATEGORY B

The CCSDS,

considering

(a) that earth station group delay calibrations must include all equipment used for ranging measurement;

(b) that earth station group delay calibrations require frequency translation to close the loop between the earth station's transmitting and receiving equipment;

(c) that the group delay measurement error of the uplink and downlink ranging system, exclusive of the frequency translation, can reasonably be kept as low as 5 nanoseconds;

(d) that the group delay measurement error of the frequency translation equipment can be kept as low as 3 nanoseconds;

(e) that other factors affecting group delay measurement error can reasonably be kept as low as 3 nanoseconds;

(f) that these measurement error contributions are largely independent, and the total error formed from the root sum squares of the individual error contributions is less than 7 nanoseconds (1-σ);

(g) that for navigation purposes, 2 meter range accuracy (1-σ) is sufficient for most Category B missions in the 8400-8450 MHz band;

(h) that a ground station group delay variation of no more than 7 nanoseconds is consistent with 2 meter range accuracy, allowing for additional range error sources including media and spacecraft delay variation;

recommends

that the earth station's 7145-7190 MHz uplink/8400-8450 MHz downlink group delay be calibrated with an accuracy better than, or equal to, 7 nanoseconds (1-σ) for Category B missions.

2.6.12 SPACECRAFT TRANSPONDER IF AND AGC AMPLIFIER BANDWIDTHS FOR COHERENT OPERATION

This recommendation has been deleted (CCSDS resolution [TBD]).

~~The CCSDS,~~

~~**considering**~~

~~(a) that most space agencies utilize spacecraft receivers employing phase-locked loops;~~

~~(b) that most of these receivers are implemented as double conversion superhetrodyne radios with two stage i.f. bandpass filters, and automatic gain controls (AGC);~~

~~(c) that a spacecraft's transponder is said to be operating coherently if its receiver is phase-locked to a signal,~~ f_r ~~, an earth station and the spacecraft's transmitted signal,~~ f_t ~~, is a rational multiple of~~ f_r ~~, such that:~~ $f_t = (m/n)f_r$ ~~, where m and n are integer numbers and the ratio (m/n) is called the transponder turnaround frequency ratio;~~

~~(d) that the predetection i.f. bandpass filters' bandwidths and the carrier AGC loop's bandwidth are very important in determining the spacecraft receiver's phase-locked loop operation;~~

~~(e) that the predetection bandwidths must be neither too large nor too small because the former can result in a degraded signal-to-noise ratio while the latter produces false locks during acquisition of the earth-to-space link;~~

~~(f) that for Category A missions, where the earth-to-space signal strength can vary both rapidly and substantially, it is the practice to design AGC loops with a fast response;~~

~~(g) that for Category B missions, where the earth-to-space signal strength generally changes slowly and slightly, it is the practice to design AGC loops with a slow response;~~

~~(h) that, when the spacecraft's receiver is operating in an unlocked mode, the AGC amplifier's gain is determined by the total received signal plus noise power while, when it is operating in a phase-locked mode, the AGC amplifier's gain is determined solely by the received carrier's signal power;~~

~~**recommends**~~

~~(1) that the spacecraft transponder's turnaround frequency ratios be selected from those contained in Section 2.6 of this book;~~

~~(2) that the spacecraft's transponder have two-sided predetection filter bandwidths of not less than 250 kHz followed by a second filter of not less than 3 kHz;~~

~~(3) that, for Category A missions, spacecraft transponders be designed to permit selection of the two-sided carrier AGC loop bandwidth over a range of at least 15 Hz to 45 Hz depending upon mission conditions;~~

~~(4) that, for Category B missions, spacecraft transponders be designed to permit selection of the two-sided carrier AGC loop bandwidth over a range of at least 1 Hz to 3 Hz depending upon mission conditions;~~

~~(5) that the spacecraft transponder's AGC include coherent and non-coherent detectors.~~