REJECTION OF USER NOISE: CDMA

CDMA = CODE DIVISION MULTIPLE ACCESS

WE HAVE SEEN HOW DIRECT-SEQUENCE AND FREQUENCY-HOPPING SPREAD SPECTRUM SYSTEMS CAN OVERCOME CHANNEL INTERFERENCE AND BROADBAND (NOISE) INTERFERENCE.

IN A CODE-DIVISION-MULTIPLE ACCESS SYSTEM, THE AIM IS TO TRANSMIT MANY RADIO MESSAGES ON A COMMON FREQUENCY BAND - AND USE THE PROPERTIES OF SPREAD-SPECTRUM SIGNALS TO CORRECTLY DEMODULATE THE WANTED SIGNAL IN THE PRESENCE OF OTHER SPREAD SPECTRUM SIGNALS - WHICH ACT LIKE NOISE.

EACH USER OF A CDMA SYSTEM HAS A UNIQUE PN-SEQUENCE USED TO SPREAD THE DATA OVER THE AVAILABLE BANDWIDTH. ALTHOUGH BOTH FHSS AND DSSS CAN BE USED, WE WILL ONLY LOOK AT DSSS

BENEFITS OF CDMA

THE EXTRA COMPLICATION OF CDMA OVER OTHER MULTIPLE ACCESS TECHNIQUES IS JUSTIFIED BY THE IMPROVEMENTS IN

* CAPACITY/SPECTRAL EFFICIENCY
* IMPROVEMENT IN QUALITY - FOR EXAMPLE IMPROVED SPEECH QUALITY
* IMPROVED SYSTEM RELIABILITY FOR EXAMPLE REDUCED NUMBER OF DROPPED CALLS, IMPROVED INTERFERENCE REJECTION CAPABILITY.

CDMA SYSTEM CAPACITY

UNDER SOME ASSUMPTIONS WE CAN DEVELOP A SIMPLE THEORY FOR THE CAPACITY OF A CDMA SYSTEMS

- THAT IS HOW MANY SIMULTANEOUS USERS CAN WE SUPPORT

THE ASSUMPTIONS;

1) POWER CONTROL - FOR EXAMPLE IN THE CASE OF DIGITAL CELLULAR SYSTEMS THIS MEANS ENSURING THAT ALL MOBILE-TO-BASE SIGNALS ARE RECEIVED AT THE SAME POWER LEVEL (- IF THIS IS NOT THE CASE WE HAVE A NEAR-FAR PROBLEM)

2) ALL USERS COMMUNICATIONS OCCUPY ALL OF THE AVAILABLE BANDWIDTH

USING THE DIGITAL CELLULAR SYSTEM EXAMPLE, ASSUME THAT A "CELL" CAN SUPPORT "N" MOBILE USERS - WE ALSO NEED TO ASSUME THAT COMMUNICATION IS DUPLEX BETWEEN SUBSCRIBERS AND THE CELL'S BASESTATION - COMMUNICATION DIRECTLY TO REMOTE SUBSCRIBERS (MOBILES) IS NOT POSSIBLE EXCEPT VIA THE BASE STATION.

FOR N USERS, THE COMPOSITE UPLINK RECEIVED SIGNAL S, WILL CONSIST OF A SINGLE WANTED SIGNAL AND N-1 UNWANTED - INTERFERING USERS ALSO EACH HAVING SIGNAL POWER S (UNDER THE POWER CONTROL ASSUMPTION)

HENCE, THE SIGNAL TO INTERFERENCE RATIO IS;

S - SIGNAL POWER FOR ALL USERS

$$\frac{S}{I} = \frac{S}{(N-1)S} = \frac{1}{(N-1)}$$

THE ENERGY PER BIT E_b IS;

$$E_b = \frac{S}{R}$$

R - DATA RATE

THE INTERFERENCE POWER-SPECTRAL-DENSITY IS;

$$I_o = \frac{\text{INTERFERENCE POWER}}{\text{BANDWIDTH}} = \frac{S(N-1)}{BW_{ss}}$$

HENCE; $$\frac{E_b}{I_o} = \frac{S/R}{(N-1)\,S/BW_{ss}} = \frac{BW_{ss}/R}{N-1}$$

SOLVING FOR N;

$$N = 1 + \frac{BW_{ss}/R}{E_b/I_o}$$

FOR $N \gg 1$ $\quad N \simeq \dfrac{BW_{ss}/R}{E_b/I_o}$

THIS IS A ZERO-ORDER APPROXIMATION FOR CDMA SYSTEM CAPACITY.

* THIS MODEL ASSUMES ALL CHANNELS ARE IN USE SIMULTANEOUSLY AND CONTINUOUSLY. – VOICE ACTIVITY FACTOR

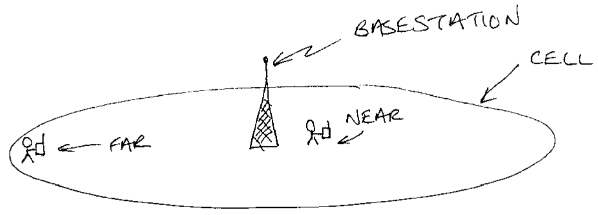
POWER CONTROL

IN DERIVING THE EQUATION FOR CHANNEL CAPACITY WE ASSUMED THAT THE MOBILE TRANSMITTER WAS CONTROLLED IN SUCH A MANNER THAT THE RECEIVED POWER AT THE BASE FROM EACH OF THE USERS WAS IDENTICAL.

WITHOUT VERY GOOD POWER CONTROL CDMA CELLULAR SYSTEMS, MULTIPLE ACCESS COMMUNICATIONS IS IMPOSSIBLE USING DIRECT-SEQUENCE (ALSO FHSS TO A LESSER EXTENT.)

THE NEAR-FAR PROBLEM

CONSIDER THIS SITUATION;



SUPPOSE BOTH MOBILES TRY AND COMMUNICATE WITH THE BASE STATION USING THE SAME TRANSMITTER POWER (A FEW WATTS TYPICALLY)

THE DIFFERENCE IN POWERS RECEIVED AT THE BASE STATION MIGHT BE >60dB (FREE-SPACE-PATH-LOSS)

HENCE THE NEAR MOBILE APPEARS AS A WIDEBAND JAMMER, JAMMING THE SIGNAL FROM THE FAR MOBILE.

THE ONLY SOLUTION TO THIS NEAR-FAR PROBLEM IS A STRINGENT POWER CONTROL SYSTEM FOR THE UPLINK – IT DOESN'T HAPPEN ON THE DOWN LINK AS THE BASE STATION CAN TRANSMIT ALL MULTIPLE ACCESS SIGNALS WITH EQUAL POWER.

⑦

TABLE 9-3. IS-95 DS-CDMA Digital Cellular System Parameters

Parameter	Forward Link	Reverse Link
Frequency band (MHz)	869–894	824–849
Access method	DS/CDMA-FDMA	DS/CDMA-FDMA
Cell-reuse pattern	Single-sector reuse	Single-sector reuse
Modulation	BPSK with Walsh orthogonal covering	64-ary orthogonal signaling
DS spreading	QPSK spread, period = 2^{15} with modulation shaping	OQPSK spread, period = 2^{15} with modulation shaping
Chip rate (Mchips/s)	1.2288	1.2288
FEC	Rate $\frac{1}{2}$, k = 9 convolutional code	Rate $\frac{1}{3}$, k = 9 convolutional code
Interleaving	Block interleaver, duration = 20 ms	Block interleaver, duration = 20 ms
Scrambling	Decimated $2^{42} - 1$ length user sequence	$2^{42} - 1$ length user sequence
Receiver structure	Three-branch Rake receiver	Four-branch Rake receiver
Speech coder Method Data rates	 QCELP 9.6, 4.8, 2.4, 1.2 kbps, rate determined by VAD	 QCELP 9.6, 4.8, 2.4, 1.2 kbps, rate determined by VAD
Frame duration (ms)	20	20
Diversity methods	Frequency diversity: wideband signal Time diversity: interleaving Path diversity: multipath Rake	Frequency diversity: wideband signal Time diversity: interleaving Path diversity: multipath Rake + antenna diversity

⑧

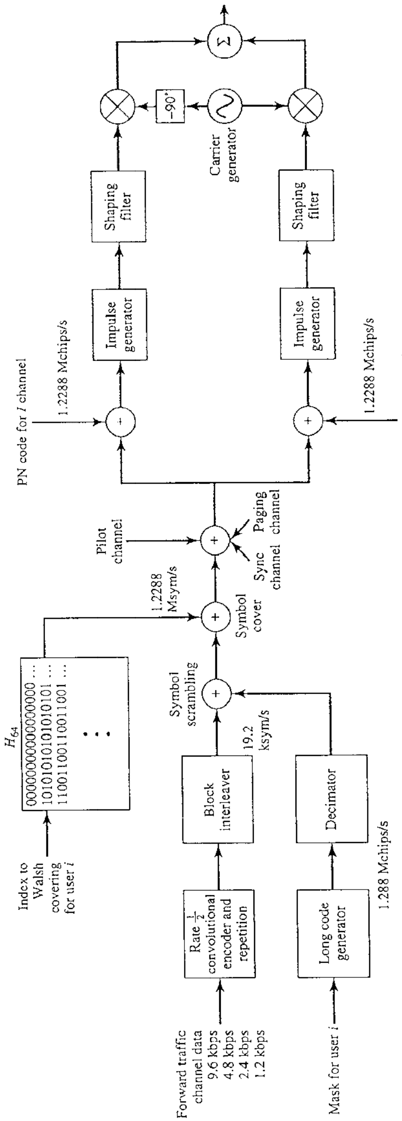


FIGURE 9-7. Detailed IS-95 transmitter structure for forward link.

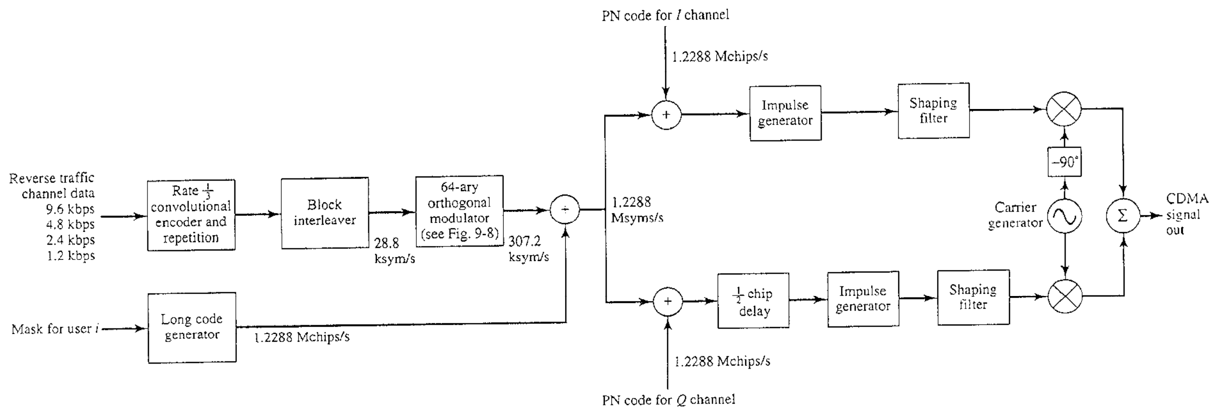


FIGURE 9-9. Detailed IS-95 transmitter structure for reverse link.

TABLE 9-8. GSM/DCS1800 System Specifications

	GSM System	DCS1800 System
Frequency bands		
Mobile transmit	890–915 MHz	1710–1785 MHz
Base transmit	935–960 MHz	1805–1880 MHz
Channels per carrier	8	
Channel bit rate	270.83 kbps	
Channel spacing	200 kHz	
Modulation	$B_bT = 0.3$ GMSK	
Symbol alphabet size	Binary, differentially coded	
Co-channel interference protection	≤12 dB	
Time slot duration	0.58 ms	
Frame duration	4.6 ms	
Frequency-hopping rate	216.68 hops/s	
Channel coding		
Type	Convolutional	
Rate		
Speech channel	$\frac{1}{2}$,1	
Signaling channels	$\frac{1}{2}$	
Interleaving depth	Eight-block diagonal interleaving for speech channel	
Maximum channel delay to be equalized	16 μs	
Speech coder		
Type	RPE/LTP-LPC	
Rate	13.0 kbps	
Frame length	20 ms	
Block length	260 bits	
Classes	Class I: 182 bits Class II: 78 bits	
Gross speech rate with FEC coding	22.8 kbps	
Frequency accuracy	Base station: 0.05 ppm Mobile station: 0.1 ppm	

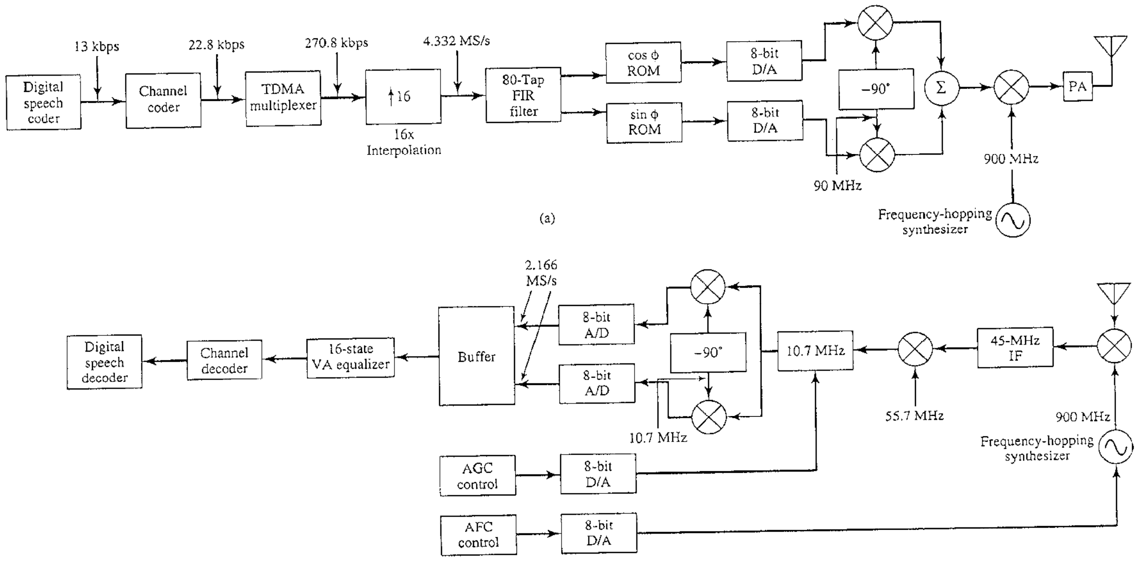


FIGURE 9-17. Block diagram of a GSM transceiver: (a) transmitter; (b) receiver.