IEEE 802.11
802 LAN Access Method for Wireless Physical Medium

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TITLE: **RADIO AIR INTERFACE CHANNEL MODULATION PARAMETERS**

SUMMARY

The following points are assumed given:

1) A spreading code shall be used to the extent that it is advantagerous, and solely for the purpose of mitigating time dispersion in the medium
2) The occupied spectrum is bounded by assigned frequency bands
3) That the duration of a symbol must be less than some decayed amplitude of an improbably long measured or assumed impulse response
4) That the data transfer rate should be as high as permitted by the available frequency space, as limited by impulse response in the medium and as limited by the speed of processing circuits of acceptable current-drain and cost

Within these considerations, it is necessary to find the boundaries of the feasible. A Table is shown with the time and path length dimensions for symbol lengths of 7, 11 and 31 chips and for various data transfer rates from 1 to 16 Mb/s. The data rates shown can be increased by a factor of 2 or 4 if 4 or 16 suitable symbol values are available. The data transfer rate can be redoubled by sending a second channel in the same frequency space in phase quadrature. The table is based on a bandwidth requirement of 1.7 chips/Hz for quadrature phase transmission.

Some of the considerations are presented for narrowing the candidate combinations, and finally some of the reasoning is given for preferring a signal of the following description:

16 Mb/sec data transfer rate
7 chips and 2 bits per symbol
0.85 chips/Hz PSK modulation
66 MHz bandwidth

RADIO AIR INTERFACE CHANNEL MODULATION PARAMETERS

FUNDAMENTAL CONSIDERATIONS

A spreading code may be used to form a symbol of several chips. The values of 7, 11 and 31 are commonly recognized as possibilities which are representative of all of the values that might be chosen.

Chip Period

Each chip has a period that is measure of the time resolution. If the time it takes two dfferent signal rays to reach the receiver differs by the chip period, the two rays may be detected independently and a decision taken from their combined values. If the spacing is less, the two rays will combine with a random phase relationship that produces Rayleigh distributed fading. It is desirable to have the shortest possible chip length permitted after other factors are considered.

Symbol Period

A symbol also has a period which is limited in duration by the time spread of the impulse response of the medium. If energy from the current synbol is still present when energy from the next symbol begins to be received, then energy from two different symbols will be added together in detecting each. Since impulse spreading is not constant but has a fluctuating shape and relative amplitude in each instant that it is present, the designer can only make the symbol long enough so that degradation to the point or error is improbable but not impossible. For a given environment, there is a minimum symbol length that must be chosen by the designer.

In the Table above, the periods are shown in time and distance. Larger rooms with greater distance between walls will generally have larger time differences between rays reach an antenna by different paths. A physical interpretation of an environment may be aided by geometry and difference in path length for predicatable mechanisms.

Matching Environment and Symbol Period

An impulse response is generally present as an average of many individual measurements all with common context. With some license it is possible to look at such a shape and say that it is 12 dB down after some period of time now called the average time dispersion. A good length for a symbol is greater than the time dispersion, but not a lot greater.

If the symbol period is far greater, then the chips will not resolve path length differences for small values of chips per symbol. For large values of chips/symbol, the occupied spectrum will preclude maximized data rate.

It may be seen that the measurements displayed by Papazian and Achatz[1] provide dimensions that directly influence possible selections. It does not take too much study of this contribution to see that a high data rate in the environment of Figure 8 US West Room 3200 (open plan office) is a substantial challenge for high data rates.

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1 "Wideband Propagation Measurements for Wireless Indoor Communication," P. B. Papazian and R. J. Achatz, NTIA-ITS, Boulder CO--802.11-92/83 July 92

LINEAR CORRELATION AND PROCESSING GAIN

It is often assumed that the purpose of spreading is to discriminate against co-users of the bandwidth expected to be narrow-band and in the aggregate of less power than the desired signal. In a maximized data capacity environment the interference between members of the same system is dominant. The spacing between simultaneous and independent users is reduced until this condition is obtained for maximum spectrum utilization. In this circumstance, the spreading code is used for increased resistance to time dispersion in the medium, reduced level variation from Rayleigh fading and may be used to create code set channelization for contiguous user separation. It is now asserted that:

> Whatever system capacity can be gained from code division channelization, can and should be obtained by using the available code space to maximize data transfer rate.

The reference system should be a narrow-band channel with the same modulation as would be used for chipping. For a given data transfer rate, this will produce a threshhold usable signal with less transmit energy than any spread spectrum plan. The ideal spreading and demodulation will provide the minimium signal with exactly the same transmit energy and receive noise bandwidth as the pure narrow-band channel.

Any non-linearity before correlation is accomplished or any interchip or intersymbol crosstalk will cause the spread modulation to be degraded from ideal. The potential processing gain from long symbols is not realized when the signal must be amplified to logic level before the analog bandwidth is narrowed to that of the information transferred..

Using a short symbol, 7 or 11 chips, is potentially a gain of 7 or 11 or more in dealing with time dispersion compared with the equivalent narrow-band modulation, but is at best equal on the basis of required transmit energy. The short symbol may be immensely more effective than long symbols when the receive demodulation process is linear until correlation is completed. The linear methods may not be feasible for long symbols because of implementation limitations including dynamic range and battery drain which are related. It is now further asserted that:

> With short spreading patterns, near-ideal linear correlation is implementable.

SYMBOL CODING

It has long been recognized that the "Barker" characters are advantageous for use as a spreading pattern with one unique correlation peak (provided that other like characters precede and follow). It has also been established that more than one pattern may be independently detected after symbol synchronization has been established.

For the criteria of acceptable we have chosen, there are sufficient patterns for 2 bits/symbol with a 7, 11 or 13 chip symbol. Insufficient patterns have been found for 4 bits with symbol lengths up to 15 chips. Assuming that sufficient codes exist for 4 bits (16) with a 31 bit symbol, there would be no spectral utilization of power advantage over the shorter codes, however there would be a significant improvement of time resolution and fade resistance.

QUADRATURE PHASE TRANSMISSION

OQPSK is a widely recognized digital transmission technique provide 1.7 bits (chips)/ Hz spectral utilization. This signal is the composite of two BPSK signals using generating carriers 90° out of phase and with the amplitude peaks of one midway between the peaks of the other. The bandwidth utilization is double that of one alone. Whether crosstalk between phases introduced by the medium is excessively damaging can probably be determined only by experiment.

FOR VARIOUS SYMBOL LENGTHS AND DATA RATES, BANDWIDTH AND CHIP LENGTH

REF#	SYM LEN CHIPS	DATA MB/SEC	CHIP MC/SEC	NOMINAL BW MHZ	CHIP LEN NSEC	SYM LEN NSEC	CHIP LEN METERS	SYM LEN METERS	USABLE FOR 16 MB/S
1	7	1	7	8	142.86	1,000	42.86	300	
2	7	2	14	16	71.43	500	21.43	150	
3	7	4	28	33	35.71	250	10.71	75	4B/SYM
4	7	5	35	41	28.57	200	8.57	60	
5	7	8	56	66	17.86	125	5.36	38	2B/SYM
6	7	10	70	82	14.29	100	4.29	30	
7	7	12	84	99	11.90	83	3.57	25	
8	7	16	112	132	8.93	63	2.68	19	YES
9	11	1	11	13	90.91	1,000	27.27	300	
10	11	2	22	26	45.45	500	13.64	150	
11	11	4	44	52	22.73	250	6.82	75	4B/SYM
12	11	5	55	65	18.18	200	5.45	60	
13	11	8	88	104	11.36	125	3.41	38	2B/SYM
14	11	10	110	129	9.09	100	2.73	30	
15	31	1	31	36	32.26	1,000	9.68	300	
16	31	2	62	73	16.13	500	4.84	150	
17	31	4	124	146	8.06	250	2.42	75	4B/SYM

POSSIBILITIES AND SELECTION FOR SYMBOL LENGTH AND TYPE

The Figure shown above starts with symbol length values of 7, 11 and 31 chips and various common possible data transfer values. The table is after screening possibilities for an occupied bandwidth of less than 150 MHz for BPSK and a minimum data rate of 1 Mb/sec.

The choice of 16 Mb/sec as the necessary data rate is arbitrary. The procedure is equally applicable to other assumptions. Our preference is for the possibility that is highlighted using two bits per symbol but not quadrarature phase.

The possibilities shown based on 4 bits per symbol are considered unfeasible or insufficiently resistant to time uncertainty and dispersion.

FITTING PARAMETERS TO ENVIRONMENT

At first look, a symbol length of 125 nsec might seem too much for the Ref 1 environment of Figure 8 where the worst case spread observed was 181 nsec (an excess path length of 54 meters). This particular path and run for this measurement is near the maximum distance that might be used for wireless LAN. It should be considered that this data was taken without applying some of the basic antidotes.

Specifically, directive antennas at one end of the link will do a great deal to reduce this spread.[2] This reference really supports narrow-band transmission but with remedies for the ovbvious problems of time dispersion.

The choice shown would be favorable for initial experimental system work.

2 "Model Based Performance Evaluation of Sector Antenna and DFE Systems in Indoor Radio Channels;" G. Yang, K. Pahlavan and T. Holt; Worcester Polytechnic Institute, PCMRC'92 Oct 92