IEEE 802.11
Wireless Access Method and Physical Layer Specification

Title: **Discussion of Critical Timing Issues Associated with the Frequency Hop Phy**

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Abstract: This paper begins with a diagram of the CCA motion that the frequency hop group passed during the July 94 meeting, and continues with discussion and diagrams that address a variety of timing issues associated with receive to transmit switching in the Frequency hop Phy.

Introduction

This submission considers four timing topics. These are the CCA attack time, which was the subject of a success motion during the July 94 meeting, the return of the CCA command to zero, called here the CCA Decay, SIFS, and contention windows. Via this discussion the critical issues are identified. It is anticipated that this will be useful both in terms of providing a starting point for Phy specification as well as a means of communicating with the Mac group with respect to important timing parameters

CCA Attack Time

Quoting from the minutes of the July 1994 meeting of the Frequency hop group:

"Question called by Ed Geiger, seconded by John McKown, on the motion which reads

"In the presence of any 802.11 compliant FH PHY signal above [-80]dBm, the PHY must signal busy within [16]us at [90]% probability of detection for preamble and a [70]% probability detection for random data. Note: [] = TBD"

In favour 13, Against 3, Abstentions 3.

Straw Polls suggested that an absolute level was accepted, and -85 dBm was accepted, with the exception of Jim McDonald who wanted the level related to the transmitted power.

Moved by Dean Kawaguchi that the CCA threshold as defined in the proceeding motions above be -85 dBm. Seconded Stuart Kerry.

Question called by Jim Renfro, seconded Jerry Loraine

Question called.

In favour 13 Opposed 0 Abstentions 2"

What this means, in diagram form, is depicted in Figure 1 for a preamble input and Figure 2 for random data input. For the sake of this paper the CCA attack time will be labeled CCA_t. Per the July 1994 motion, at the end of the max CCA detection time, the probability of a Ch_busy indication is 90% if the IEEE 802.11 frequency hop compliant input signal is at least -85 dBm and modulated with a 1,0 preamble or 70% if the modulation is random data.

From Figure 1 it is apparent that CCA_t is the sum of delay through the receiver from the antenna input to the baseband retimed data output, RD_t, plus the amount of time need for measurement of the signal, MA_t, to determine if it meets the requirements of RF level and IEEE 802.11 frequency hop compliance. Thus,

$$CCA_t = RD_t + MA_t$$

The July 1994 motion did not address the issue of Ramps. It is proposed here that the Ramps not be included in the timing specification in order to avoid ambiguity. This is depicted in figure 3. Ramps may either be short or long, and according to the current status of the subgroup proceedings, there may or may not be modulation present during the ramp. It is therefore recommended that the CCA attack time, CCA_t, be measured with an input that has a ramp of less than 1 uSec.

Ramps actually only apply to the preamble case. The question exist, however, as to how an IEEE 802.11 frequency hop compliant signal may appear do be initiated with random data. Compliant 802.11 frequency hop signals, however, may be jammed for a period by a another RF signal, or may vary in signal strength. Figures 4 and 5 address these issues. The author suggest that the frequency hop subgroup review these cases and determine if the scope of definition is complete. Are there other scenarios that should be considered? From a standards point of view, it would appear that the specification depicted in Figure 3 addresses the real world environments represented by Figures 4 and 5.

CCA Decay

The second set of diagrams address the opposite CCA function which occurs at the end of an 802.11 frequency hop compliant signal. Here the ch_busy line must return to zero. The question is how soon? Figure 10 depicts the simple case of no interference. Since the timing of the return to zero of the CCA line is the time reference for contention window activity, it is important to control the bounds of CCA^{-1}_t to within some defined tolerance. (This issue is discussed further below.) It is proposed here that that time be reference from the end of the last bit of the MPDU as depicted in Figure 10. Here CCA^{-1}_t is equal to the sum of the receiver delay, RD_t, and the measurement time, MD_t. Thus,

$$CCA^{-1}_t = RD_t + MD_t$$

Figure #11 and 12 depict more complex scenarios were interference masks the tail portion of the 802.11 frequency hop compliant transmission.

In Figure 11, interference begins after the start of the MPDU portion of the transmission. In this scenario, the receiver correctly receives the MPDU length information contained in the PHY signaling field. It is proposed here that the ch_busy signal remain high for the predicted length, L, of the packet or fragment plus a ramp period plus the $CCA^{-1}{}_t$ period as illustrated in figure 11. (The same result would occur if the 802.11 frequency hop compliant signal dropped below the CCA threshold before the completion of the length, L.) This is clearly the correct process since once the MPDU length information is received, it is known that the signal will be on the channel for a certain period of time whether or not it is received correctly by the unit in question.

Referring to figure 11 it is pointed out that the $CCA^{-1}{}_t$ is reference to the signal present at the antenna terminal. It is important to point out however, that the process of using the predicted length, L, is a baseband process. At baseband, the ch_busy line should be held high for a length of time $CCA^{-1}{}_t$ minus the receiver delay, RD_t.

In Figure 12 interference begins before the start of the MPDU portion of the transmission. In this case the length field will not be read and L is not known. Two possibilities seem evident

1. A rationale case could be made to require the ch_busy line to be high for the length of the minimum signal i.e., an ACK packet.

2. A rationale argument could also be made for allowing the ch_busy line to return to low if either the compliant signal is overridden by interference (modulation is effected) or if the level of the compliant signal falls below the CCA threshold. For this first condition, there needs to be a limit on the C/I at which ch_busy can return to zero and when. As a straw man proposal it is suggested here that the receiver ch_busy be maintained high if C/I is greater than 20 dB and that ch_busy be allowed to return low immediately if C/I falls below 20 dB.

This paper recommends the C/I criteria

SIFS

The next timing issue addressed here is the receive to transmit interval associated with SIFS.

A basic function of an 802.11 compliant module is to transmit a signal following the termination of an existing signal on the channel. One example is the ACK transmission following successful reception of a fragment or packet.

Figure 20 address the SIFS issue. An ACK is only returned if a signal is correctly received. Thus, it is reasonable to assume that the length field was correctly received. The receiving unit therefore knows precisely when the end of message will occur, at baseband. To this it is appropriate to add an allocation for the Mac to calculate the crc and to provide the PHY with the command to switch to transmit mode and return an ACK. These allocations are depicted in Figure 20. The SIFS period must be at least the sum of the receiver delay, RD_t, plus the MAC crc delay, TM_1, plus the PHY receive to transmit switch over, R/T_t, plus the transmit delay, TD_t, plus the transmit ramp, RP_t. Thus,

$\mathrm{SIFS} = \mathrm{RD}_t + \mathrm{TM}_1 + \mathrm{R/T}_t + \mathrm{TD}_t + \mathrm{RP}$

This address the time delay associated with a unit returning an ACK . In terms of receiving a ACK, it is proposed here that a simple test would suffice, wherein a transmitting unit would be required to receive a ACK at specified sensitivity that follows with the SIFS timing specified above.

Contention Window Timing

The final timing issue addressed in this submission is the contention window process. Consider the scenario depicted in Figure 30. Here units Y and Z are poised ready to transmit a packet in the contention period. Unit Y has been assigned contention window # 5 and unit Z has been assigned contention window #6. The issue addressed here is whether or not unit Z will recognize that unit Y has begun transmitting in window #5 and therefore defer its transmission which was intended to start in contention window #6. To study this case, first it will be assumed that both Y and Z receive the signal from Z at the same time and that they both have the same contention window time reference.

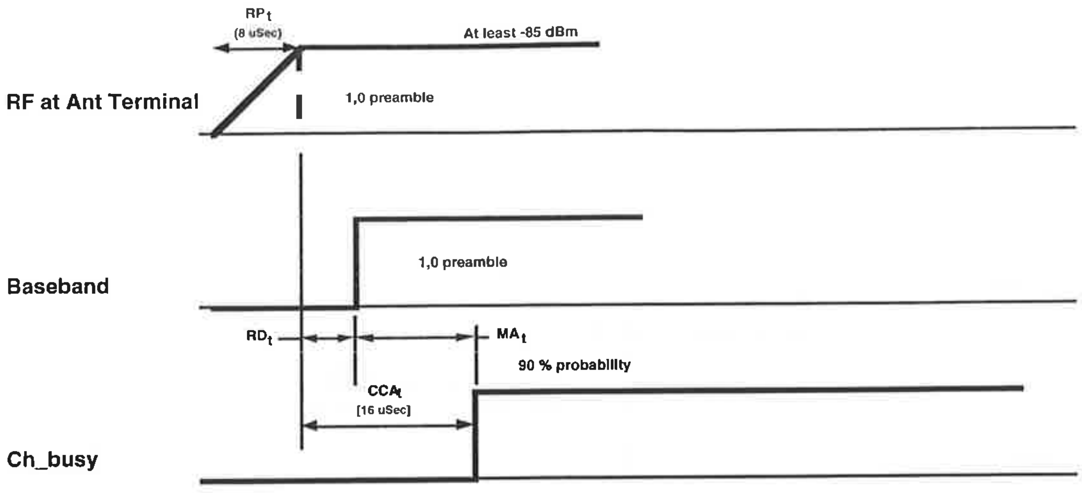
In this case, the activities that take place in window #5 are first a delay for the Mac to confirm that there was no existing transmission from the previous window, M_2. Then, the transceiver will be switched from receive to transmit, $\mathrm{R/T}_t$. Following a transmitter delay, TD_t, the transmitter will ramp up, RP_t, and begin to transmit. Assuming propagation delays are negligible the transmission from Y must exist for at least the period of time required by an observing unit to perform a CCA detection, CCA_t. Thus, the nominal contention window time, CW_t, is,

$\mathrm{CW}_t(\mathrm{Nom}) = M_2 + \mathrm{R/T}_t + \mathrm{TDt} + \mathrm{CCA}_t$

In an actual environment, however, there will be a need to allow for tolerances in the assumed timing references, for propagation and for margin. Thus,

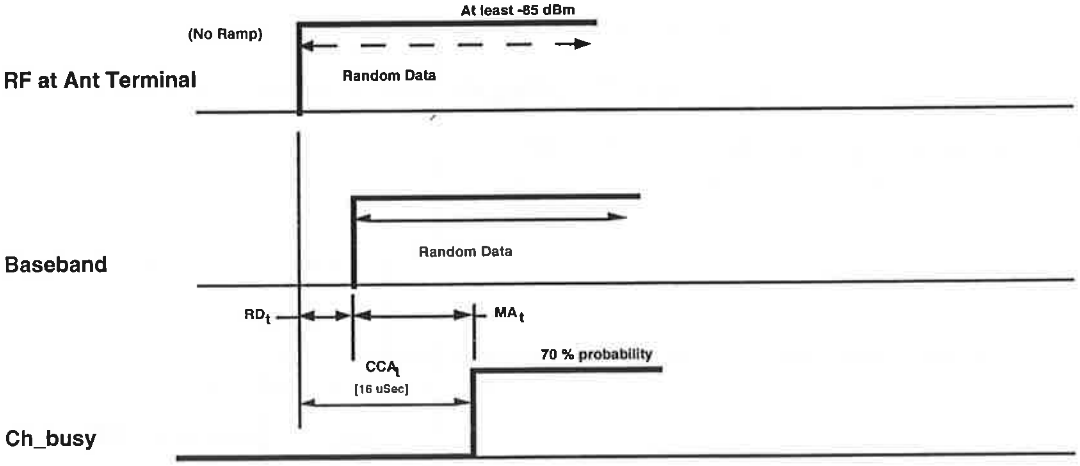
$$\begin{aligned}\mathrm{CW}_t(\mathrm{Max}) = \mathrm{CW}_t(\mathrm{Nom})\\ + \mathrm{CCA}^{-1}{}_t(\mathrm{Max}) - \mathrm{CCA}^{-1}{}_t(\mathrm{Min})\\ +2 \times \text{Prop delay} + \text{Margin}\end{aligned}$$

It is clear that $\mathrm{CW}_t(\mathrm{Max})$ could be significantly lower if a more accurate timing reference were available. One based on the predicted length would be very accurate. The problem with using the predicted length is that not all observers will necessarily see the beginning of all messages. The Mac group could, if it chooses, provide high priority short contention windows to units that receive the length field and assign longer, further out contention windows to units deriving their timing from the decay of the RF signal.



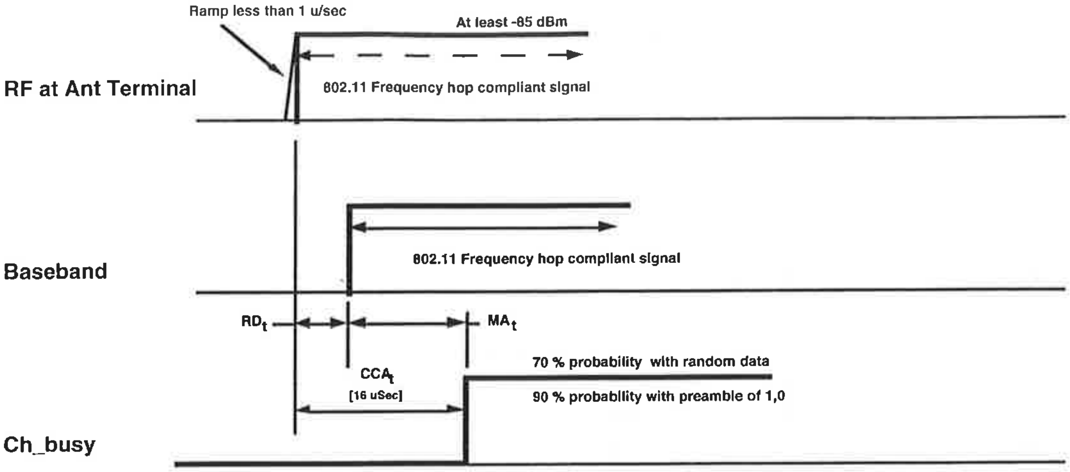
CCA Definitions for Preamble Input

Figure # 1



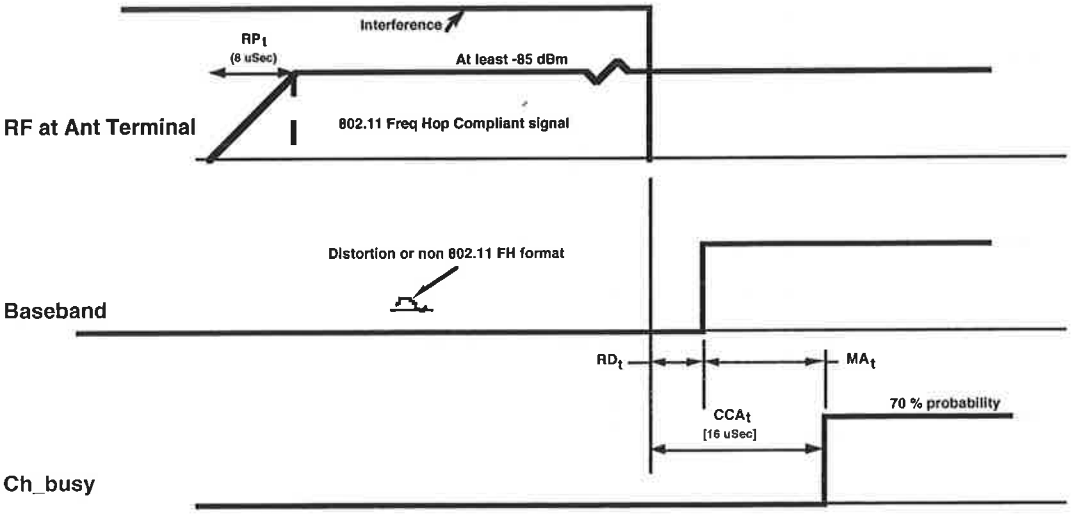
CCA Definition for Random Data Input

Figure # 2



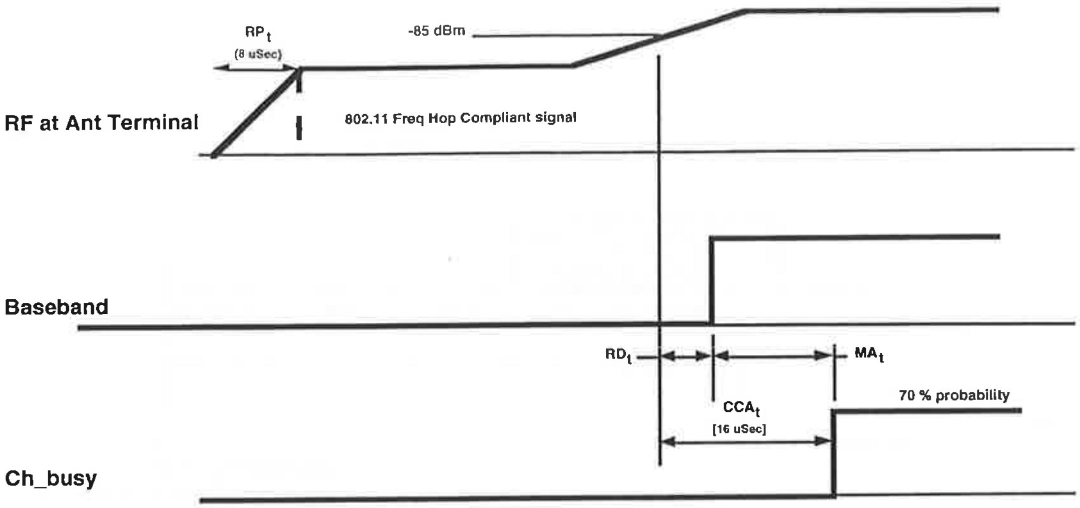
CCA Measurement

Figure # 3



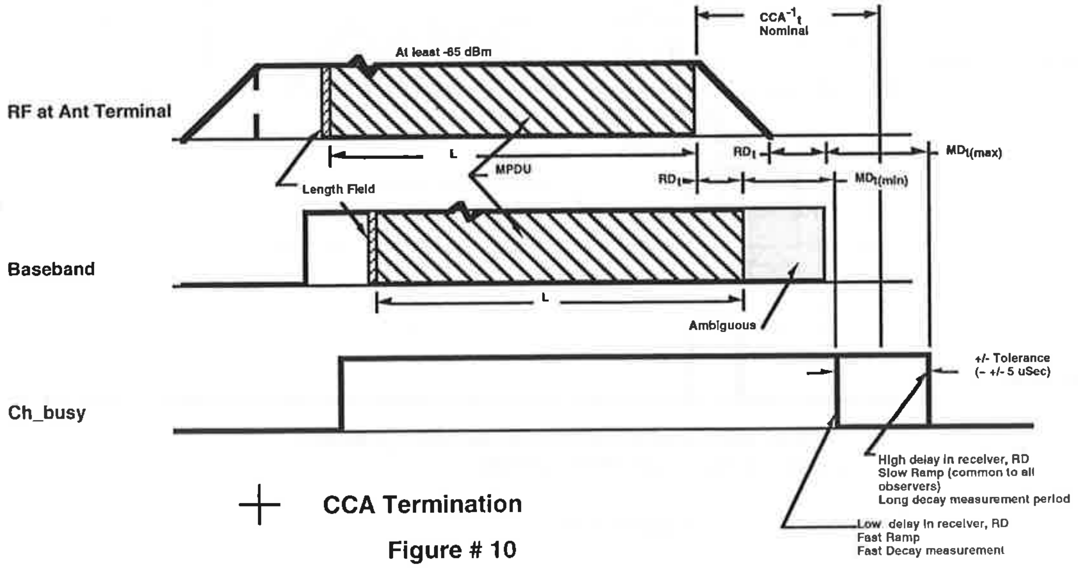
CCA with Interference

Figure # 4



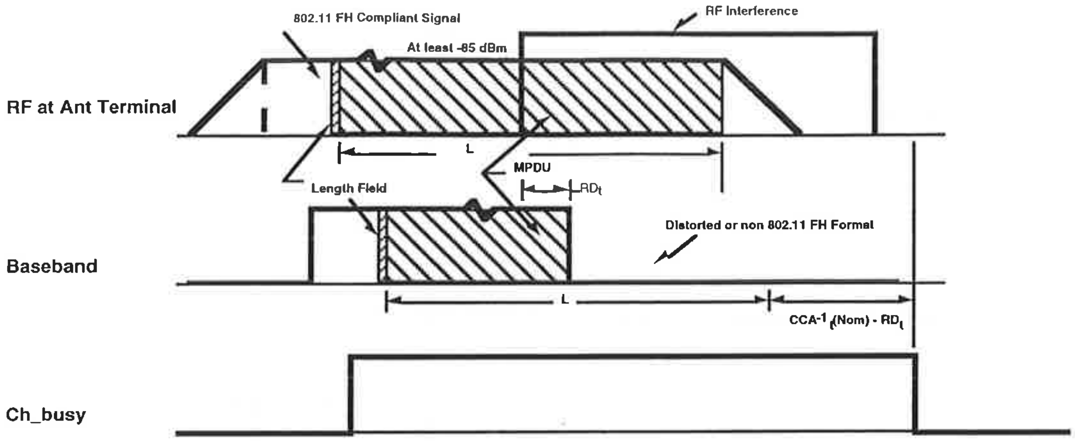
CCA with Variation in Signal Level

Figure # 5



CCA Termination

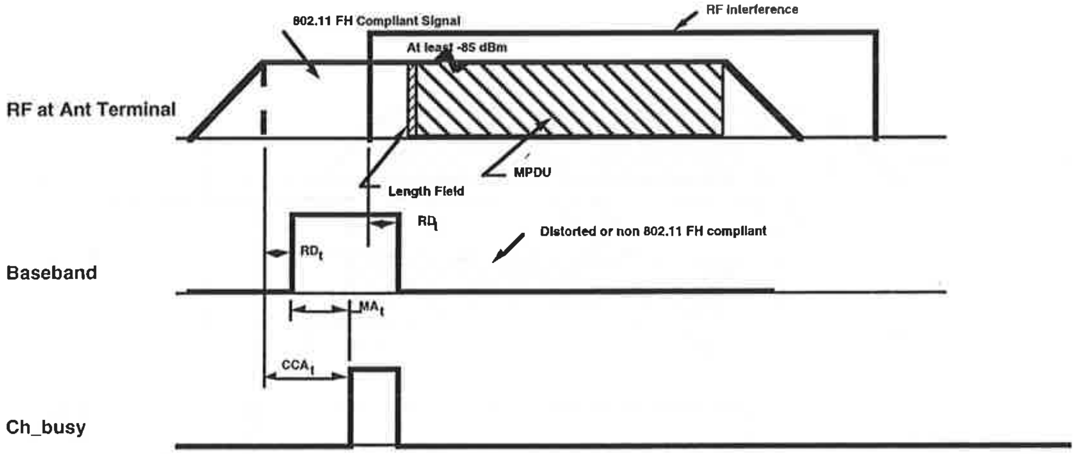
Figure # 10



Note; The Ch_busy line is held high for the predicted length of the MPDU, L, plus an allocation for the nominal length of CCA$^{-1}{}_t$ minus the time delay of the receiver RD$_t$

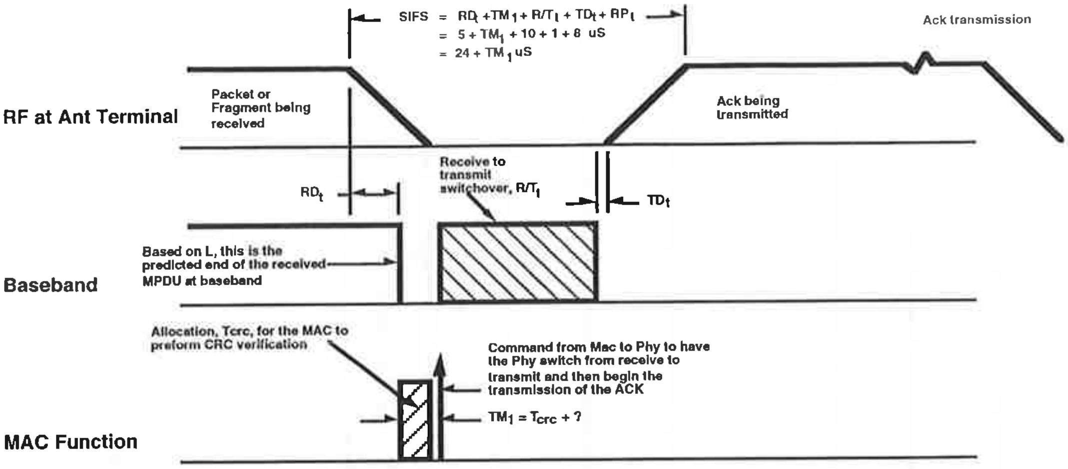
CCA Termination with interference present

Figure # 11



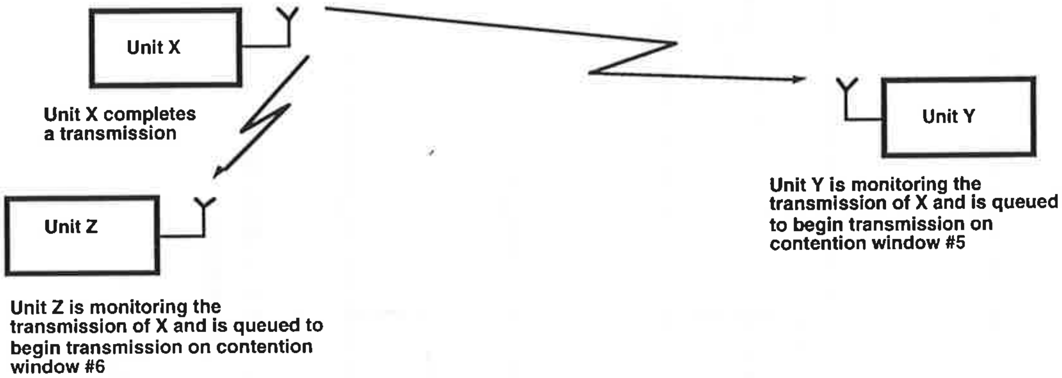
CCA Termination with interference present before the start of the MPDU

Figure # 12

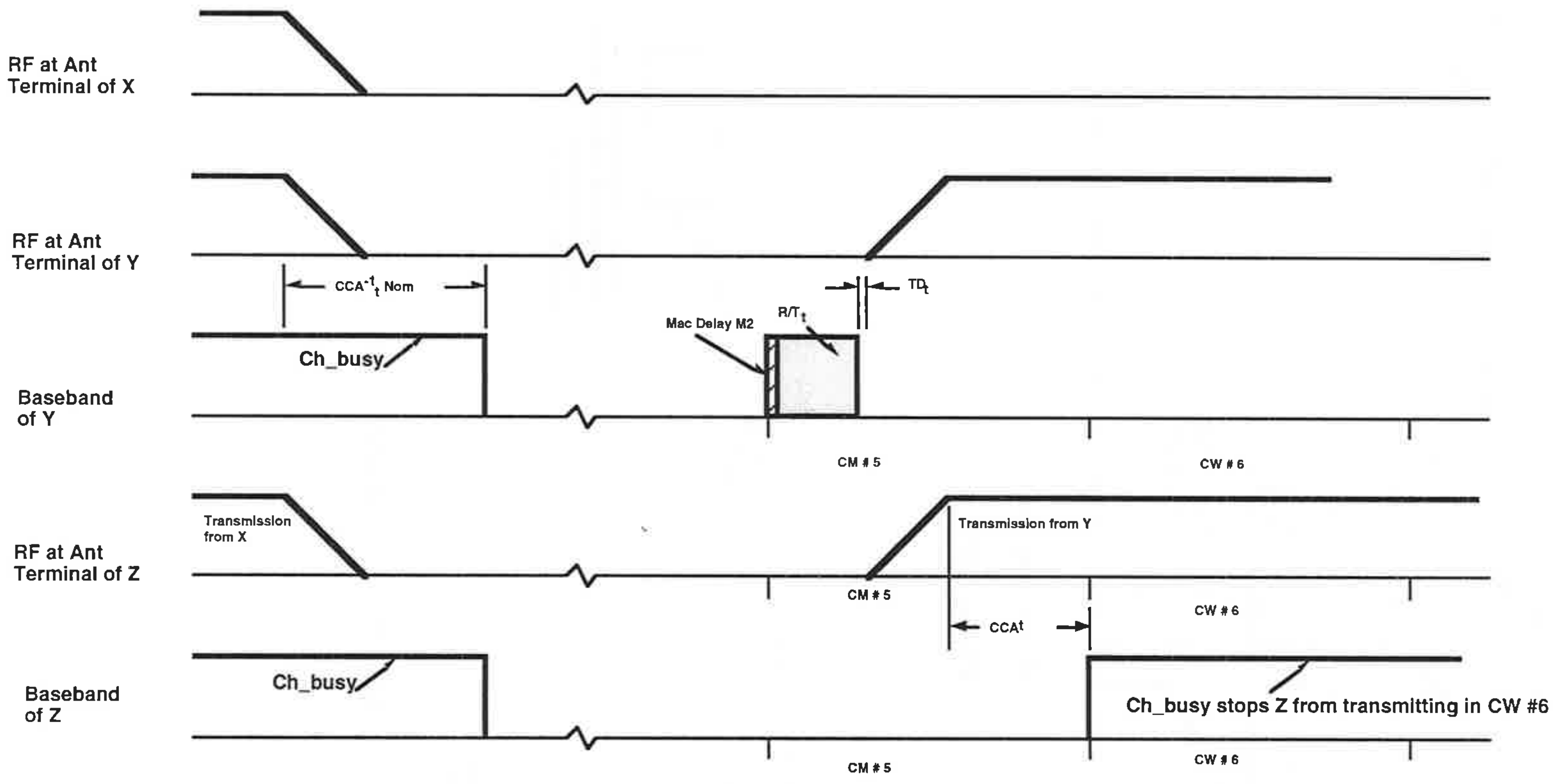


SIFS Analysis

Figure # 20



Scenario for Contention Window Analysis
Figure #30



Contention Window Analysis

Nominal Case Illustrated

Figure # 31

$CW_t\ (Nom) = M2 + R/T_t + TD_t + CCA_t$

$\sim 3 + 10 + 1 + 16$

$\sim 30\ uS$

$CWt\ (Max) = CWt\ (Nom)$

$+ CCA\text{-}^{1}_{t}\ (Max) - CCA\text{-}^{1}_{t}\ (Min)$

$+ 2 * Prop\ Delay + Margin$

$\sim 30 + 10 + 2 + Margin$

$\sim 42\ uS + Margin$