Dynamic Spectrum Sensing by Multiband OFDM Radio for Interference Mitigation

Marilynn P. Wylie-Green
Nokia Research Center
6000 Connection Drive
Irving, TX 75039

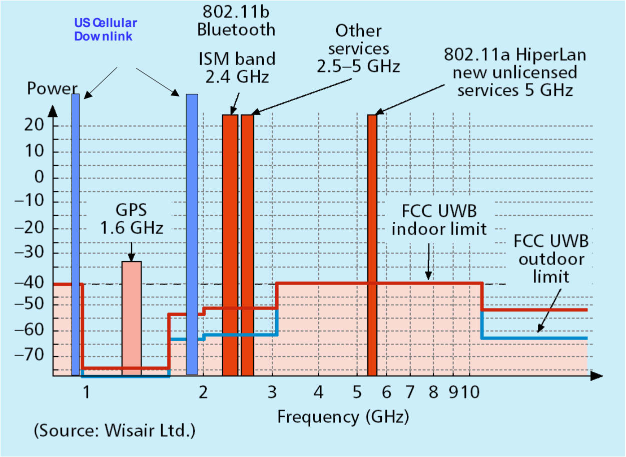
***Abstract*— MB-OFDM Ultrawideband radio will have to coexist with narrowband radio services that operate over the 3.1-10.6 GHz band. In order to coexist with these other radio systems without becoming a source of harmful interference, MB-OFDM system designers will have to develop methods to dynamically detect their presence so that the appropriate avoidance techniques can be implemented whenever it is determined that MB-OFDM transmissions will pose a source of harmful interference. This paper investigates the feasibility of detecting a downlink transmission from an indoor Fixed Service (FS) system when the MB-OFDM radio collects measurements over a number of consecutive OFDM symbol periods. The analysis shows that when the Fixed Service signal received by the MB-OFDM device is at a power level of -98 dBm, that it is possible to achieve a false alarm probability of 10^{-4} and a missed detection probability of ~ 10^{-6} when using the measurements that are obtained over 70 consecutive OFDM symbol periods (~ 22 us). Since the Fixed Service sub-channel time duration is 200 us, our results imply that the required measurement time is reasonable with respect to the duration of time that the Fixed Service signal is on the air.**

Keywords-component; MB-OFDM, ultrawideband, detection, coexistence

I. INTRODUCTION

In February of 2002, the FCC liberated the airwaves and laid the regulatory framework for the unlicensed use of approved UWB devices over the 3.1 – 10.6 GHz bands (see Fig. 1). By transmitting very low power signals across several Gigahertz of the frequency band, government-approved UWB systems will share a broad swathe of spectrum with an array of government-owned, privately licensed and unlicensed incumbent radio systems.

UWB Wireless Personal Area Network (WPAN) radios can offer 50 to 500 times greater data rates than Bluetooth is currently able to do; thus it is clearly wrestling in a different class. It is envisioned that UWB will replace high-speed cables and audio-video connections in homes and offices or that it will be used for accurate location estimation for low data-rate applications. However, due to its low transmit power (-41.3 dBm/MHz) the application range is limited to maximum of 10–20m @100 Mbit/s and 2-4m@480Mbit/s.



(Source: Wisair Ltd.)

Figure 1. Spectrum allocation of UWB in the U.S. Overlaying light red area is the UWB emission mask with a maximum emission limit of -41.3 dBm/MHz. (Source: Wisair).

MB-OFDM Ultrawideband radio [1] promises to deliver the expected data rates and there are numerous applications that will benefit from its introduction in to the realm of wireless communication (see Figure 2). However, it will have to coexist with various narrowband radio services that operate over the 3.1-10.6 GHz band, including Fixed Services, Radio Astronomy Services, Fixed Wireless Access and other services. In order to coexist with these other radio systems without becoming a source of harmful interference, MB-OFDM system designers will have to develop methods to first dynamically detect the presence of narrowband radio transmissions and, secondly, they will have to develop methods that can be used to reduce the level of interference that MB-OFDM transmissions will impose over the victim receivers band whenever it is determined that these transmissions will harmfully interfere with the performance of the other radio system.

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Figure 2. Potential UWB applications for mobiles include wireless remote displays, fast synchronization and downloading (e.g. newspapers, movies, games, videos), ad hoc networks (e.g. for local multiplayer games), and content sharing, Internet access and high quality printing.

This paper considers the feasibility of requiring the MB-OFDM radio to dynamically detect the ongoing transmissions from narrowband radio systems. In particular, we construct a study which enables us to determine the parameters that most affect the ability of the MB-OFDM radio to detect transmissions from an indoor Fixed Service system.

II. BACKGROUND ON MB-OFDM PHY

As defined by FCC regulations [2], UWB is a very wide bandwidth signal that occupies more than 500MHz or has a fractional bandwidth of at least 20%. To achieve such a wide bandwidth signal with a reasonable level of complexity, different approaches for transmission can be considered.

MB-OFDM Ultrawideband radio conforms to this bandwidth requirement by dividing its available band (3.1 – 10.6 GHz) into fourteen 528 MHz "bands" (see Fig. 3). As illustrated in the figure, the first twelve bands are grouped into four band groups, while the last two bands are grouped into a fifth band group. Currently, the only band group that is mandatory is Band Group #1. Use of the other band groups will be added over time as the technology matures.

Fig. 4 illustrates one example of how the OFDM symbols can be transmitted. The coded data is spread using two different Time Frequency Coding (TFC) mechanisms. The first, which is called Time Frequency Interleaving (TFI), interleaves the coded data over three bands according to a pre-specified pattern. In the example below, the pattern has a period of three OFDM symbols. However, in practice, the period can be much longer. The second TFC mechanism, called Fixed Frequency Interleaving (FFI), sends the coded information over a single band.

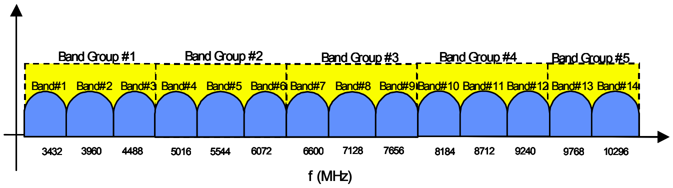

Figure 3. Diagram of the band group allocation over the 3.1 – 10.6 GHz band.

A guard interval of 9.5 ns is appended to each OFDM symbol and a cyclic prefix (zero padding) is pre-pended to the beginning of each OFDM symbol. The guard interval is selected in order to ensure that there is adequate time for the transmitter or receiver to switch between different frequencies in the band group. The duration of the cyclic prefix is 60.6 ns and it is included for robustness against multipath.

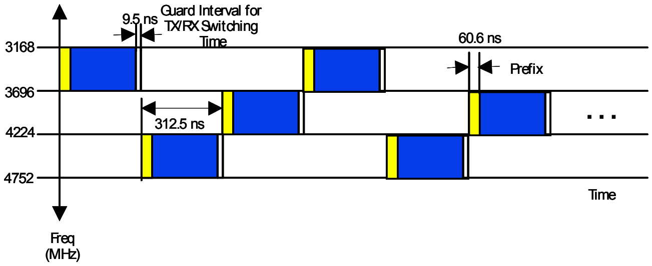

Figure. 4. Example TFC for an MB-OFDM System over Band Group #1.

Fig. 5 shows one possible transmitter architecture for the MB-OFDM system, which is very similar to the architecture for a conventional OFDM physical layer, except that the carrier frequency changes based on the TFC.

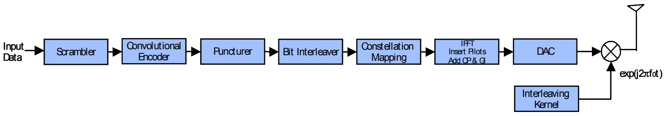

Figure. 5. Example TFC for an MB-OFDM System over band group 1.

Table 1 summarizes the key parameters of the MB-OFDM technology. Of the data rates listed, only 53.3, 106.7 and 200 Mbps are mandatory. This system uses an OFDM scheme that utilizes 128 sub-carriers per band, 122 of which are used to transmit the information. Of the 122 data carriers, there are 100 used as data carriers, 10 used as guard carriers and 12 used as pilot carriers.

OFDM is an attractive candidate for several reasons: first, for its capability to survive in rich multi-path environments – which has been proven by its use in DVB-T and WLAN applications and second, for its adaptability to different spectrum regulatory environments since individual channels and OFDM sub-carriers can be switched on and off according to the prevailing regulatory requirements. In the context of interference avoidance and in light of the need to protect incumbent radio systems, this feature makes MB-OFDM an especially attractive Ultrawideband system.

TABLE 1. MB-OFDM SYSTEM PARAMETERS

Parameter	Value
Total bandwidth (without hopping)	528 MHz
Number of data sub-carriers	100
Number of defined pilot carriers	12
Number of undefined pilot carriers	10
Number of total sub-carriers used	122
Sub-carrier frequency spacing	4.125 MHz(-528MHz/128)
IFFT (FFT) period	242.42 ns
Cyclic prefix	60.61 ns (=32/528 MHz)
Guard interval duration	9.47 ns (-5/528 MHz)
Symbol interval	312.5 ns
Data rates	53.3, 55, 80, 106.7, 110, 160, 200, 320, 400, 480 Mbps

Currently, the peak data rate offered by this OFDM-based solution starts at 53.3 Mbps and goes up to 480Mbps. However, it is conceivable that in the future, that it may go as high as 1 Gbps with the use of an appropriate multilevel modulation technique, such as 16QAM.

III. UWB SPECTRUM REGULATION

In their landmark ruling in February 2002, the Federal Communications Commission allocated 7.5 GHz of spectrum for approved UWB devices to operate at a an emission limit of -41.3dBm/MHz over the 3.1 – 10.6 GHz band (see Fig. 1). Additional protection limits of –51.3 dBm/MHz for indoor devices and –61 dBm/MHz for portables between 2 – 3.1 GHz have drawn some opposition - especially from cellular operators and from the device manufacturer's side - since these limits are not sufficient to protect cellular phones from significant degradation without several meters of separation from the UWB transmitter. Fortunately, MB-OFDM devices will probably achieve a more co-existence friendly spectrum mask than that which can be achieved by strict use of the FCC's limits.

In the ITU, TG1-8 (which is under SG1) studies compatibility issues between UWB and other radio systems and Working Party 8F, which promotes global development of the IMT-2000 system, is heavily involved in discussions about UWB emission limits. Based on the current contributions from the both groups, the ITU will end up with much tighter recommendations for UWB out-of-band emission limits than the FCC. In 2004, the EU gave a mandate to TG3 under CEPT to prepare a recommendation emission mask for Europe. The work is still ongoing, but the first draft report (Report 64) was released in late 2004 with a rather pessimistic view on UWB coexistence with other systems, in particular Fixed Services and Fixed Satellite Services. The UK's regulatory body OFCOM instead provided much more positive analysis using an FCC-like mask with improved out-of-band limits to protect current cellular and wireless systems below 3 GHz, with potentially lower in-band transmit power as well.

Activity that is currently going on in the regulatory regime (such as in TG3) and the pessimistic results of Report 64 have become a strongly motivating factor for studying the detection capabilities of Ultrawideband radio. In particular, since MB-OFDM is built upon the OFDM paradigm, we can exploit its design in order to facilitate the detection (and avoidance) of other radio systems.

In the analysis to follow, we provide more insight into how the MB-OFDM radio can exploit its normal processing units (such as the FFT) in order to detect a Fixed Service transmission and we also discuss reasonable system parameters (measurement times, etc.) for the MB-OFDM radio to be able to detect the victim transmission with a certain level of reliability.

IV. HYPOTHESIS TESTING

In this paper, we consider a Fixed Service system that is based on the IEEE 802.16e specification. The system parameters used for the downlink transmission for this system are provided in Table 2.

TABLE 2. FIXED SERVICE PARAMETERS

Parameter	Value
Occupied bandwidth, B	4.7 MHz
Noise figure	6 dB
Noise floor	-108 dBm/MHz
Noise power in bandwidth	-101.28 dBm
SNR (QPSK ½, AWGN)	3.7 dB
Sensitivity, P	-98 dBm
Subchannel time duration	200 us

For simplicity, it is assumed that the Fixed Service signal is centered on one of the MB-OFDM sub-carrier frequencies [1] and that it is actively transmitting. Hence, the Fixed Service signal that is detected by the MB-OFDM receiver at the output of M successive 128-point FFTs contains a single bin in which the Fixed Service signal is always present. The Fixed Service signal is modeled as a complex Gaussian random variable with variance equal to the Fixed Service signal power (-98 dBm, from Table 2).

The MB-OFDM receiver collects measurements over M successive OFDM symbol periods in order to determine if the narrowband interference is present. The duration of each OFDM symbol on a 528 MHz band is 0.242 us and the FFT processor in the receiver computes a 128 point FFT every 0.3125 us. Thus, at the end of the measurement period, the MB-OFDM transmitter has collected a total of M 128-point FFTs. From the total set of measurements, it constructs a 2M x

1 vector of signal components for every point (frequency bin) in the FFT. The 2M components are constructed from the in-phase and quadrature components of the incoming signal and are arranged such that the first M components of this vector consist of the in-phase components of the received signal while the second M components consist of its corresponding quadrature components.

From Table 1, the bandwidth of the Fixed Service signal is 4.7 MHz. The MB-OFDM carrier spacing is 4.125 MHz. Hence, we can closely approximate (for the purposes of simplifying the analysis) that the Fixed Service signal occupies only one frequency bin. Thus, the hypothesis under question is whether or not a Fixed Service signal is detected in that one bin over the observation time.

Given that the Fixed Service system is actively transmitting, then under the null hypothesis (H0), the MB-OFDM receiver measures thermal noise only in a particular frequency bin. Under the alternate hypothesis (H1), the MB-OFDM receiver measures the FS transmission along with thermal noise.

A. Null Hypothesis

Under the null hypothesis, the 2M x 1 measurement vector can be modeled as follows:

$$\mathbf{r}_{H_{01}}(l) = \begin{bmatrix} y_{I,1}(l) \\ \\ y_{I,M}(l) \\ y_{Q,1}(l) \\ \\ y_{Q,M}(l) \end{bmatrix} = \begin{bmatrix} n_{I,1}(l) \\ \\ n_{I,M}(l) \\ n_{Q,1}(l) \\ \\ n_{Q,M}(l) \end{bmatrix}, \qquad (1)$$

$$l = 1, \quad ,128, l \neq l_{\text{bin}}.$$

Here, $y_{I,m}$ and $y_{Q,m}$ represent the in-phase and quadrature components of the received signal. $n_{I,m}$ and $n_{Q,m}$ denote the in-phase and quadrature components of the thermal noise. They are modeled as zero-mean (real) Gaussian random variables with a variance of $\sigma_{n1}^2/2$, where σ_{n1}^2 is defined as the total thermal noise power per FFT bin.

Since the carrier spacing of the MB-OFDM signal is approximately the same as the bandwidth of the Fixed Service downlink signal, an appropriate model for the Fixed Service signal present at the input to the MB-OFDM receiver is to assume it as being narrowband noise with a bandwidth roughly equal to 4.125 MHz. Under this modeling assumption and considering a noise figure of 6.6 dB, we can calculate the noise power per FFT bin as:

$$\begin{aligned} \sigma_{n1}^2(\text{dBm}) &= -114\ \text{dBm/MHz} + 6.6\ \text{dB} + 10\log_{10}(4.125\ \text{MHz}) \\ &= -101.23\ \text{dBm} \end{aligned} \qquad (2)$$

Quantization error introduces an additional source of noise over the MB-OFDM receiver's bandwidth. Assuming that 5 bit ADCs (Analog-to-Digital Converters) are used in the receiver, that the receiver noise figure is 6.6 dB, and that the filter bandwidth is close to 500 MHz, the variance of the thermal noise at the output of the ADC is given by:

$$\begin{aligned} \sigma_n^2(\text{dBm}) &= -114\ \text{dBm/MHz} + 6.6\ \text{dB} + 10\log_{10}(500\ \text{MHz}) \\ &= -80.4\ \text{dBm}. \end{aligned} \qquad (3)$$

For the case in which only thermal noise is present, the thermal noise floor determines the AGC (Automatic Gain Control) setting. Setting the peak noise level to be 9 dB higher than the average results in a peak input power to the ADC being $x_{\max}^2$ = -80.4+9 = -71.4 dBm. Since the ADC has R=5 bits, the resulting quantization noise power may be estimated to be:

$$\sigma_q^2 = \tfrac{1}{3} 2^{-2R} x_{\max}^2 \sim -106.27\ \text{dBm}. \qquad (4)$$

Since $\sigma_q^2 << \sigma_n^2$, we can neglect its contribution in the modeling of our system and only consider the effects of the thermal noise, σ_n^2.

Under the null hypothesis, the probability density function of the Gaussian observation vector is given by:

$$p_{\mathbf{r}(l)|H_0}(\mathbf{r}(l) \mid H_0) = \left[(2\pi)^M \left|\mathbf{K}_0\right|^{1/2}\right]^{-1} \exp\left[-\tfrac{1}{2}\mathbf{r}(l)^T\, \mathbf{Q}_0 \mathbf{r}(l)\right] \qquad (5)$$

where |x| denotes the determinant of x. $\mathbf{K_0}$ denotes the covariance matrix and $\mathbf{Q_0}$ is its inverse:

$$\mathbf{K}_0 = \frac{\sigma_{n1}^2}{2} \cdot \mathbf{I}_{2M}, \mathbf{Q}_0 = \frac{2}{\sigma_{n1}^2} \cdot \mathbf{I}_{2M} \qquad (6)$$

$\mathbf{I}_{2M}$ is the 2M x 2M identity matrix.

B. Alternate Hypothesis

Under the alternate hypothesis (H_1), the receiver observes the indoor Fixed Service signal along with the thermal noise in only one of the FFT bins, l_{NBI}. Hence, under H_1 the measurement vector is given by

$$\mathbf{r}_{H_1}(l) = \begin{bmatrix} y_{I,l}(l) \\ \\ y_{I,M}(l) \\ y_{Q,1}(l) \\ \\ y_{Q,M}(l) \end{bmatrix} = \begin{bmatrix} n_{I,1}(l) \\ \\ n_{I,M}(l) \\ n_{Q,1}(l) \\ \\ n_{Q,M}(l) \end{bmatrix} + \begin{bmatrix} u_{I,1} \\ \\ u_{I,M} \\ u_{Q,1} \\ \\ u_{Q,M} \end{bmatrix}, \qquad l = l_{\text{NBI}}. (7)$$

$u_{I,m}$ and $u_{Q,m}$ respectively denote the in-phase and quadrature FS signal components that are received in the l-th FFT bin during the m-th OFDM symbol period.

The probability density function of the Gaussian observation vector is given by

$$p_{\mathbf{r}(l)|H_1}(\mathbf{r}(l)\,|\,H_1) = \left[(2\pi)^M|\mathbf{K}_1|^{1/2}\right]^{-1}\exp\left[-\tfrac{1}{2}\mathbf{r}(l)^T\mathbf{Q}_1\mathbf{r}(l)\right] \tag{8}$$

where $\mathbf{K}_1$ and $\mathbf{Q}_1$ are defined as follows:

$$\mathbf{K}_0 = \frac{\sigma_{n1}^2 + P}{2}\cdot\mathbf{I}_{2M}, \mathbf{Q}_0 = \frac{2}{\sigma_{n1}^2 + P}\cdot\mathbf{I}_{2M} \tag{9}$$

V. DETERMINATION OF THE TEST STATISTIC FOR HYPOTHESIS TESTING

The test statistic that is used for detecting the Fixed Service transmission may be derived from consideration of the likelihood ratio, which compares the ratio of the measurement's probability density function under both hypotheses to some threshold value, η. In this case, since the measurement vector is Gaussian under both hypotheses, the likelihood ratio is determined to be:

$$\Lambda(\mathbf{r}) = \frac{p_{r|H_1}(\mathbf{r}\,|\,H_1)}{p_{r|H_0}(\mathbf{r}\,|\,H_0)} = \frac{|\mathbf{K}_0|^{1/2}\exp\left\{-\dfrac{1}{2}\mathbf{r}^T\mathbf{Q}_1\mathbf{r}\right\}}{|\mathbf{K}_1|^{1/2}\exp\left\{-\dfrac{1}{2}\mathbf{r}^T\mathbf{Q}_0\mathbf{r}\right\}} \mathop{\gtrless}_{H_0}^{H_1} \eta$$

$$. \tag{10}$$

Now, taking the natural logarithm of both sides,

$$\frac{1}{2}\left(\mathbf{r}^T(l)\mathbf{Q}_0\mathbf{r}(l)\right) - \frac{1}{2}\left(\mathbf{r}^T(l)\mathbf{Q}_1\mathbf{r}(l)\right) \mathop{\gtrless}_{H_0}^{H_1} T^* \tag{11}$$

$$T^* = \ln\eta + \frac{1}{2}\ln|\mathbf{K}_1| - \frac{1}{2}\ln|\mathbf{K}_0|.$$

The above expression is equivalent to the following test:

$$\frac{1}{\sigma_{n1}^2}\mathbf{r}^T(l)\mathbf{H}\mathbf{r}(l) \mathop{\gtrless}_{H_0}^{H_1} 2T^* \tag{12}$$

$$\mathbf{H} = \sigma_{n1}^2(\mathbf{Q}_0 - \mathbf{Q}_1) = \frac{2P}{P + \sigma_{n1}^2}\mathbf{I}_{2M}.$$

This result implies that the likelihood ratio statistic can be formulated as follows:

$$\left(\frac{1}{\sigma_{n1}^2}\cdot\frac{P}{P + \sigma_{n1}^2}\right)\cdot\sum_{i=1}^{2M} r_i^2(l) \mathop{\gtrless}_{H_0}^{H_1} T^*$$

$$\sum_{i=1}^{2M} r_i^2(l) \mathop{\gtrless}_{H_0}^{H_1} T^*\cdot\left(\sigma_{n1}^2\cdot\frac{P + \sigma_{n1}^2}{P}\right) \tag{13}$$

$$\sum_{i=1}^{2M} r_i^2(l) \mathop{\gtrless}_{H_0}^{H_1} T^*\cdot\frac{(P + \sigma_{n1}^2)}{SNR}$$

Hence, the final test statistic for detection is the squared sum of the output of the FFT. Because it is the sum of the squares of 2M independent, identically Gaussian random variables, under both hypotheses the test statistic is a central chi-squared variable with *2M* degrees of freedom.

VI. PROBABILITY OF FALSE ALARM

Under the null hypothesis, the probability density function of the test statistic is given by

$$p_{l|H_0}(L\,|\,H_0) = \begin{cases} \dfrac{L^{M-1}e^{-L/2(\sigma_{n1}^2/2)}}{2^M\left(\sigma_{n1}/\sqrt{2}\right)^{2M}\Gamma(M)} & \mathrm{L} \geq 0 \\ 0 & \mathrm{L} < 0 \end{cases} \tag{14}$$

where

$$L = \sum_{i=1}^{2M} r_i^2(l) \tag{15}$$

is the test statistic and Γ(x) is the gamma function.

The probability of false alarm is the probability that the signal level *exceeds* the threshold in any one of the 127 bins that is not really occupied by the FS transmission. Hence, it can be derived using the series of calculations below:

$$\begin{aligned} P_f &= 1 - \left(\int_0^{\frac{T^*}{SNR}(P+\sigma_{n1}^2)} \frac{1}{\sigma_{n1}^{2M}\Gamma(M)} L^{M-1}e^{-L/2(\sigma_{n1}^2/2)}dL\right)^{127} \\ &= 1 - \left(\int_0^{\frac{T^*(P+\sigma_{n1}^2)}{2(\sigma_{n1}^2/2)SNR}} \frac{1}{\Gamma(M)} x^{M-1}e^{-x}dx\right)^{127} \\ &= 1 - \left(\Gamma_{inc}\left(\frac{T^*(1+SNR)}{SNR}, M\right)\right)^{127} \end{aligned} \tag{16}$$

where Γ_{inc} is Pearson's incomplete Gamma function, $\Gamma_{inc}(a,b) = \frac{1}{\Gamma(b)}\int_0^a e^{-t} t^{b-1} dt$.

Finally, letting $t = T^*(1+SNR)/SNR$, the false alarm probability for the detection of a FS transmission in one of the frequency bins is given by:

$$P_f = 1 - \left(\Gamma_{inc}(t, M)\right)^{127}. \tag{17}$$

VII. PROBABILITY OF MISSED DETECTION

Under the alternate hypothesis, the probability density function of the test statistic is given by:

$$p_{l|H_1}(L \mid H_1) = \begin{cases} \dfrac{L^{M-1} e^{-L/2\left(\left(\sigma_{n1}^2+P\right)/2\right)}}{2^M\left(\sqrt{\left(\sigma_{n1}^2+P\right)/2}\right)^{2M}\Gamma(M)} & \mathrm{L} \geq 0 \\ 0 & \mathrm{L} < 0. \end{cases} \tag{18}$$

The probability of a missed detection is just the probability that the signal level in l_{NBI} *does not exceed* the threshold given that the FS signal is actually present, and it can be calculated as follows:

$$P_m = \int_0^{\frac{T^*\left(P+\sigma_{n1}^2\right)}{SNR}} \frac{1}{2^M\left(\sqrt{\dfrac{\sigma_{n1}^2+P}{2}}\right)^{2M}\Gamma(M)} L^{M-1} e^{-\frac{L}{2\left(\frac{\sigma_{n1}^2+P}{2}\right)}} dL$$

$$= \int_0^{\frac{T^*\left(P+\sigma_{n1}^2\right)}{2\left(\frac{\sigma_{n1}^2+P}{2}\right)\cdot SNR}} \frac{1}{\Gamma(M)} x^{M-1} e^{-x} dx = \Gamma_{inc}\left(\frac{T^*}{SNR}, M\right) \tag{19}$$

As before, we define a new threshold, $t = T^*(1+SNR)/SNR$. The probability of missed detection is then given by $P_m = \Gamma_{inc}\left(t/(1+SNR), M\right)$.

VIII. COMPARISON OF THE THEORETICAL PROBABILITY OF DETECTION AND FALSE ALARM

Based on the foregoing analysis, we now compare the false alarm probability and the probability of missed detection as a function of the threshold, t, the SNR and M (the number of OFDM symbols over which the signal is observed). We define the SNR as the ratio: P/σ_{n1}^2. Expressed in dB, it is equal to 3.23 dB (-98 dBm – (-101.23 dBm)). We consider four different measurement windows: M = 40, 50, 60 and 70. These observation windows respectively correspond to measurement over 12.5 us, 15.625 us, 18.75 us and 21.875 us (since the FFT is taken once every 0.3125 us).

The false alarm and missed detection characteristics are shown in Figure 6. This figure shows that if we select M = 70 that we can obtain a false alarm probability of 10^{-4} and a missed detection probability of close to 10^{-6}. In comparison, if we select M = 60, we can obtain a false alarm probability of 10^{-4} and a missed detection probability that is close to 10^{-5}.

For M = 70, the observation period is ~ 22 us. Compared to the duration of a FS downlink burst (200 us), this represents a reasonable amount of time to detect the signal.

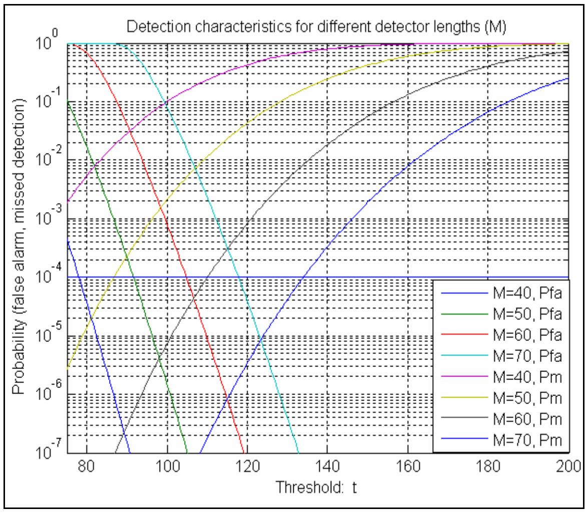

Figure 6.Characteristics for detecting the indoor Fixed Service transmissions over various observation windows for SNR = 3.23 dB.

IX. CONCLUSION

Detection of narrowband services has become an important issue for Ultrawideband spectrum regulation. Hence, it is increasingly important that Ultrawideband radio be capable of reliably detecting ongoing transmissions of narrowband radio services. In this paper, we have investigated the feasibility of requiring an MB-OFDM Ultrawideband radio to detect an ongoing Fixed Service transmission and found that it is possible to achieve a false alarm probability of 10^{-4} and a missed detection probability of close to 10^{-6} by measuring over 70 consecutive OFDM symbol periods (~ 22 us). This measurement time is reasonably short compared to the time duration of a FS downlink burst (200 us), which implies that detection is technically feasible. Although the case studied represents the simplest scenario (when the narrowband transmission falls into a single frequency bin), the analysis nonetheless suggests that the detection of narrowband transmissions over the MB-OFDM band is indeed feasible and we note that this analysis may be extended to cover more complex cases.

X. REFERENCES

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