Response to Information request EA98731, documents reference number 17744 of FCC from 18th of January 2001.

Information with regard to the Bluetooth device operates under the Frequency Hopping Spread Spectrum (FHSS) requirements.

Question 1.

Minimum channel separation requirement

The channel spacing of the device is 1 MHz. Following plots of a spectrum analyzer show the separation between peaks and adjacent channels in 79 channel mode.

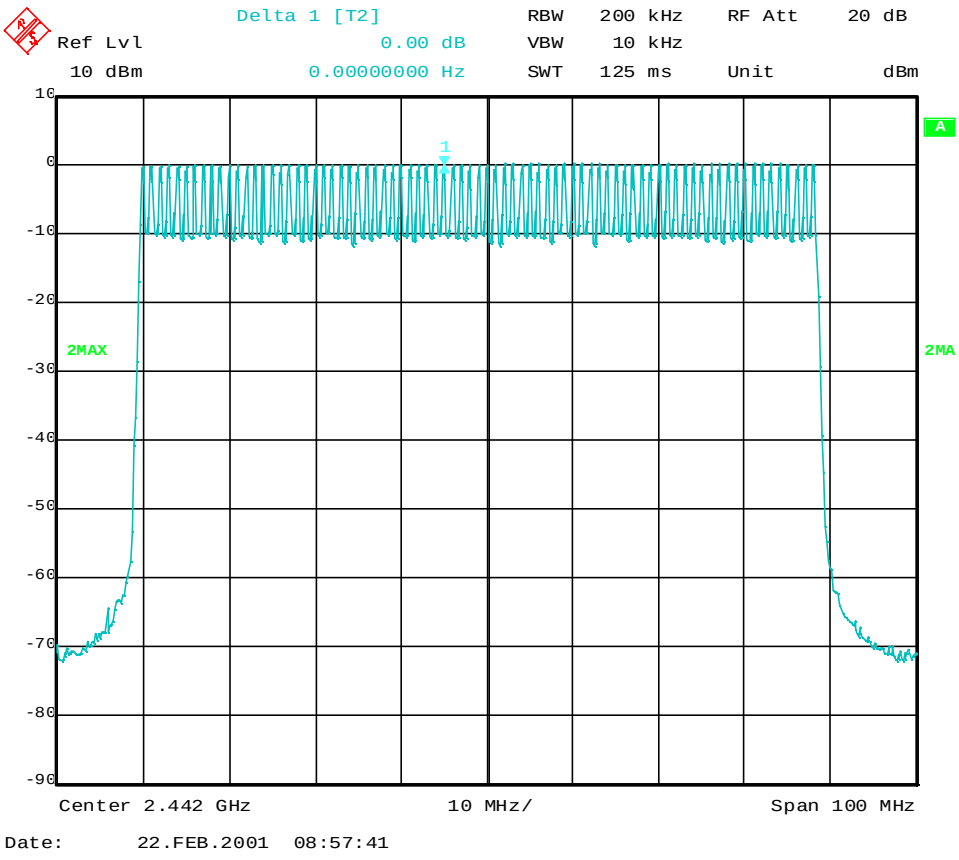

Figure 1- Complete Sequence: This figure shows the full hopping channel sequence. 79 channels with 1MHz channel separation can be seen.

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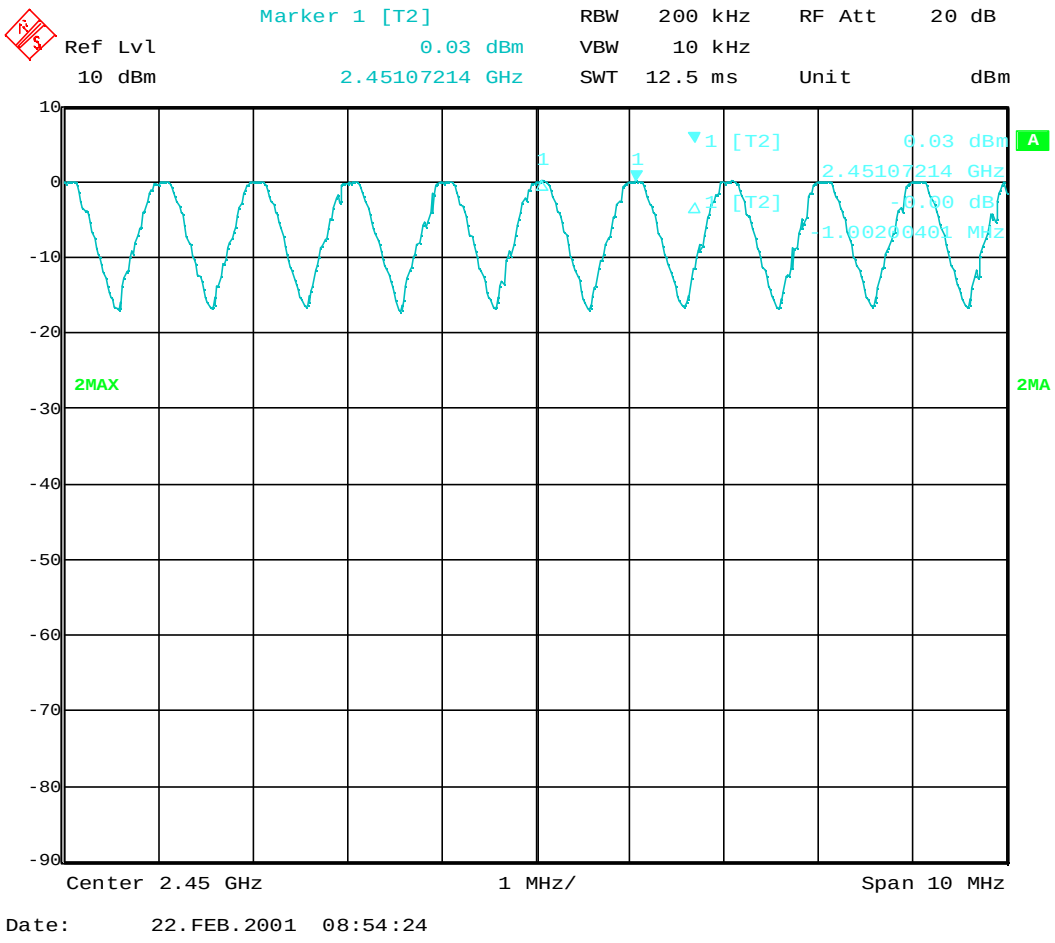

Figure 2 -Channel Spacing: This sweep was made over a span of 10 MHz to show more detail. Here from the 1 MHz channel spacing can be derived.

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Question 2.

Pseudorandom hop sequence

The pseudorandom sequence is generated in a nine-stage shift register whose 5th and 9th stage outputs are added in a module-two addition stage with the result fed back to input of the first stage.

The following are two examples of possible 79 hopping sequences with channels identified as 0 through 78. The channel numbering scheme starts with channel 0 at 2402 MHz with the 79th channel then appearing at 2480 MHz as channel 78.

Sequence example a:

01, 51, 03, 55, 05, 04, 07, 08, 72, 57, 74, 61, 76, 10, 78, 14,
09, 59, 11, 63, 13, 12, 15, 16, 17, 65, 19, 69, 21, 18, 23, 22,
33, 67, 35, 71, 37, 20, 39, 24, 25, 73, 27, 77, 29, 26, 31, 30,
41, 75, 43, 00, 45, 28, 47, 32, 17, 02, 21, 04, 19, 34, 23, 36,
33, 06, 37, 08, 35, 38, 39, 40, 25, 10, 29, 12, 27, 42, 31

Sequence example b:

55, 26, 19, 20, 23, 22, 53, 40, 57, 42, 21, 36, 25, 38, 27, 63,
31, 65, 74, 59, 78, 61, 29, 00, 33, 02, 76, 75, 01, 77, 35, 71,
39, 73, 03, 67, 07, 69, 37, 08, 41, 10, 05, 04, 09, 06, 43, 16,
47, 18, 11, 12, 15, 14, 45, 32, 02, 66, 47, 60, 49, 64, 04, 54,
06, 58, 51, 52, 53, 56, 08, 70, 10, 74, 55, 68, 57, 72, 59

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Question 3.

Use of each frequency equally on average

Every Bluetooth unit has an internal system clock that determines the timing and hopping of the transceiver. The Bluetooth clock is derived from a free running native clock, which is never adjusted and is never turned off. For synchronization with other units, only offsets are used that, added to the native clock, provide temporary Bluetooth clocks which are mutually synchronized.

The Bluetooth master determines the timing and the frequency hopping on the channel of a piconet. The hop selection scheme consists of the selection of a sequence and the mapping of this sequence on the hop frequencies. In the connection state, the clock bits to use in the hopping sequence generation are always according to the master clock.

A sending unit transmits the FHS (frequency hopping selection) packet. It contains UAP (upper address part) / LAP (lower address part) as well as clock information which is updated before retransmission in the inquiry state. The output from the selection box constitutes a pseudorandom sequence covering 79 hops.

Question 4.

Receiver matching bandwidth and synchronization

Receiver bandwidth

The receiver bandwidth in the 79 channel hopping mode is 1 MHz.

Synchronization

Synchronization within a piconet uses a system of beacon channels generated by the master unit with the remaining slave units periodically waking up and listening on a beacon channel. Beacon channels are designated by the master unit in page mode to identify channels for slave units to listen to. The beacon channel packet also contains the synchronization information required for the slave to synchronize with the master unit.

If the two Bluetooth devices have exchanged information during the last five hours, the typical time it takes to establish the connection is reduced considerably due to the ability of the paging unit to estimate at what frequency the other unit will perform the page scan.

Question 5.

Minimum number of channels

The Bluetooth device uses 79 channels in US/Europe hopping sequence mode.

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Question 6.

10 dB bandwidth plots

The occupied bandwidth of the device, which has to be below 1 MHz following the 20 dB bandwidth requirement, can be found on page 39, 40 and 41 of the test report.

Figures 3 to 5 show plots of the 10 dB bandwidth for lower, mid and upper channel.

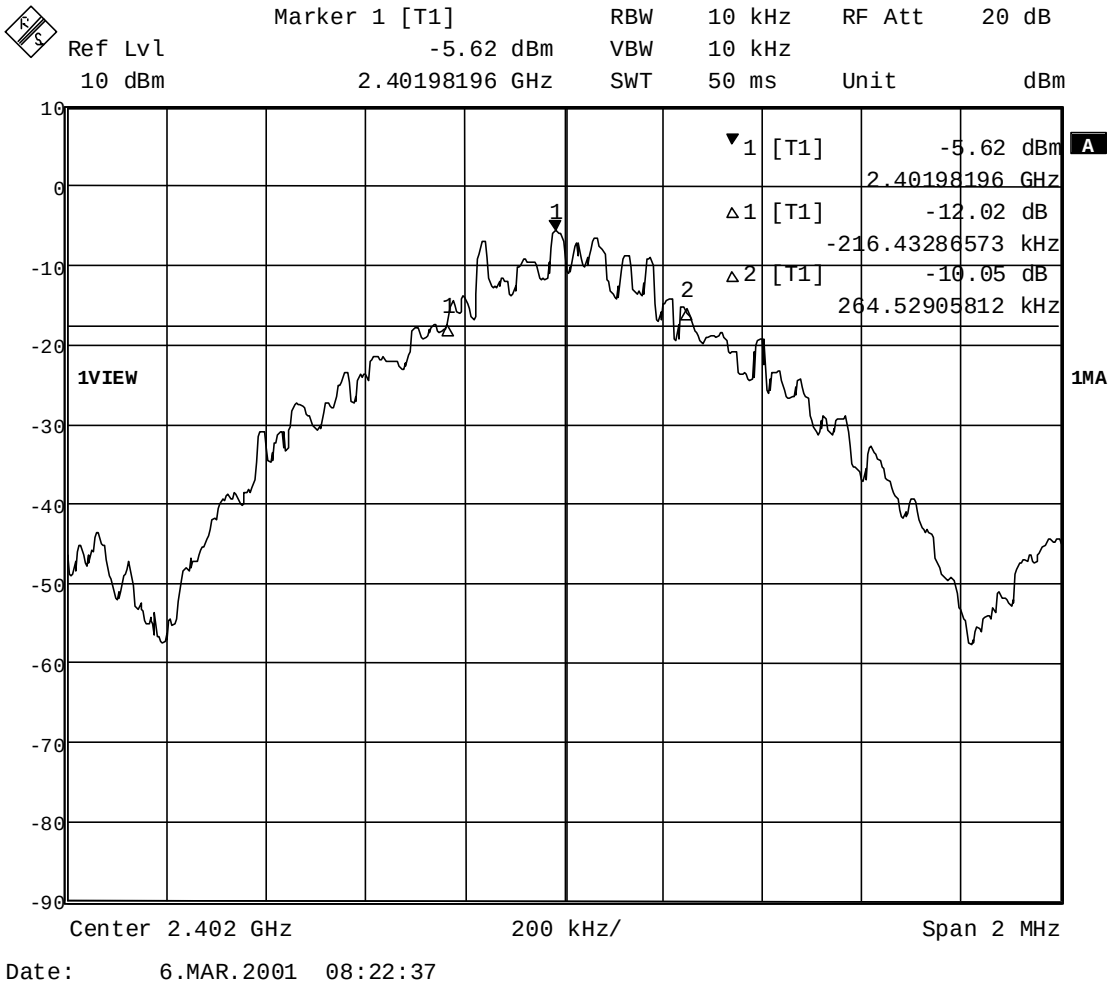

Figure 3-10 dB Bandwidth: Plot 10 dB bandwidth for lower channel: 481 MHz

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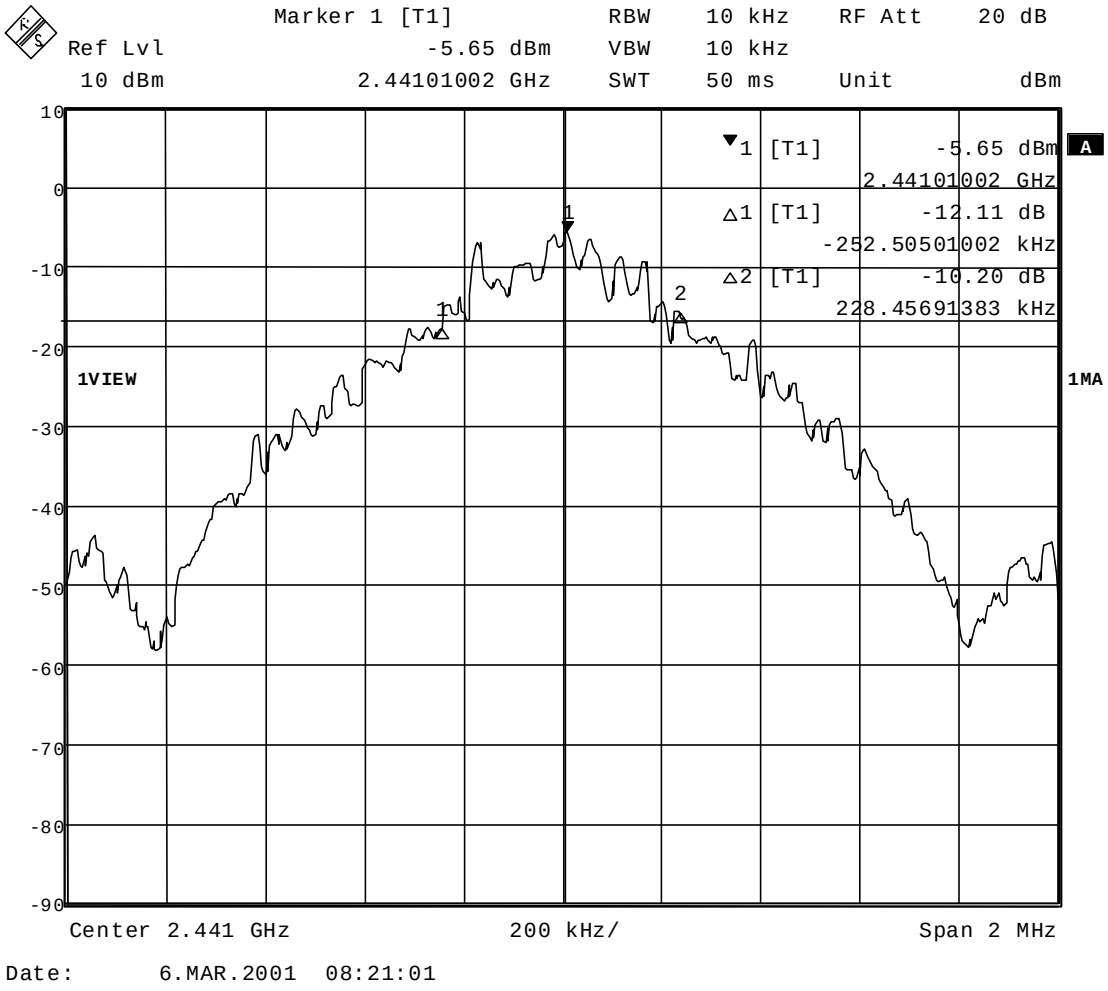

Figure 4-10 dB Bandwidth: Plot 10 dB bandwidth for lower channel: 481 MHz

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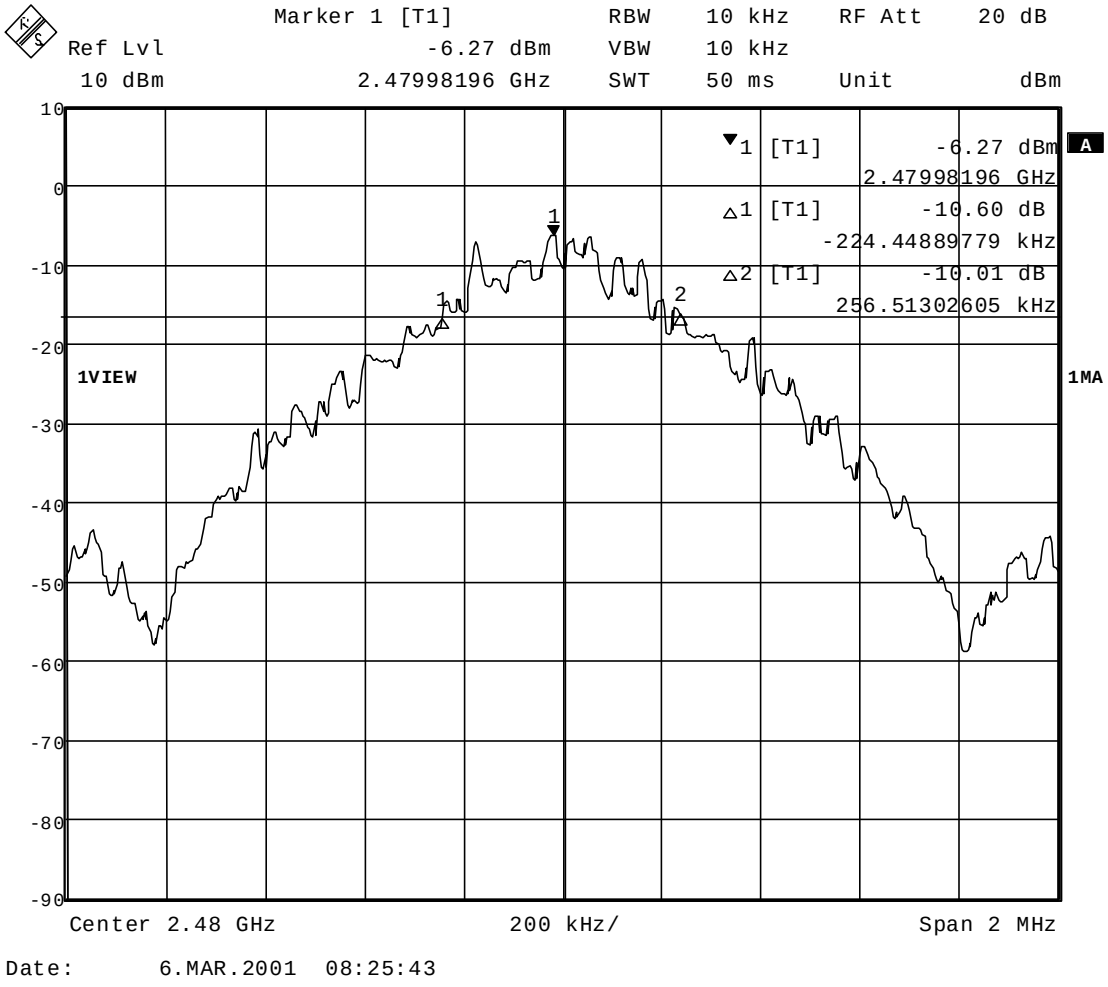

Figure 5-10 dB Bandwidth: Plot 10 dB bandwidth for lower channel: 481 MHz

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Question 7.

Average time of occupancy of any frequency (dwell time) for FH

In 79 channel hopping mode an individual transmission for the longest possible Bluetooth packet on a channel is 2.8 millisecond long. During a 30 second time period, the dwell time on a given channel is 188,5 microseconds long.

Figure 6 shows a plot with spectrum analyzer set into zero span, with a sweep time of 30 seconds. This plot shows how often a frequency is used in a 30 second time period. 65 occur on a single hopping channel. The next plot (figure 7) shows the used packet. The longest possible packet in a Bluetooth connection is 2.8 ms. That means that in the time of 30 sec there are 65 (transmissions) multiplied with 2.9 ms (with power ramping) = 188,5 ms. This is well within the requirement of maximal 400 msec.

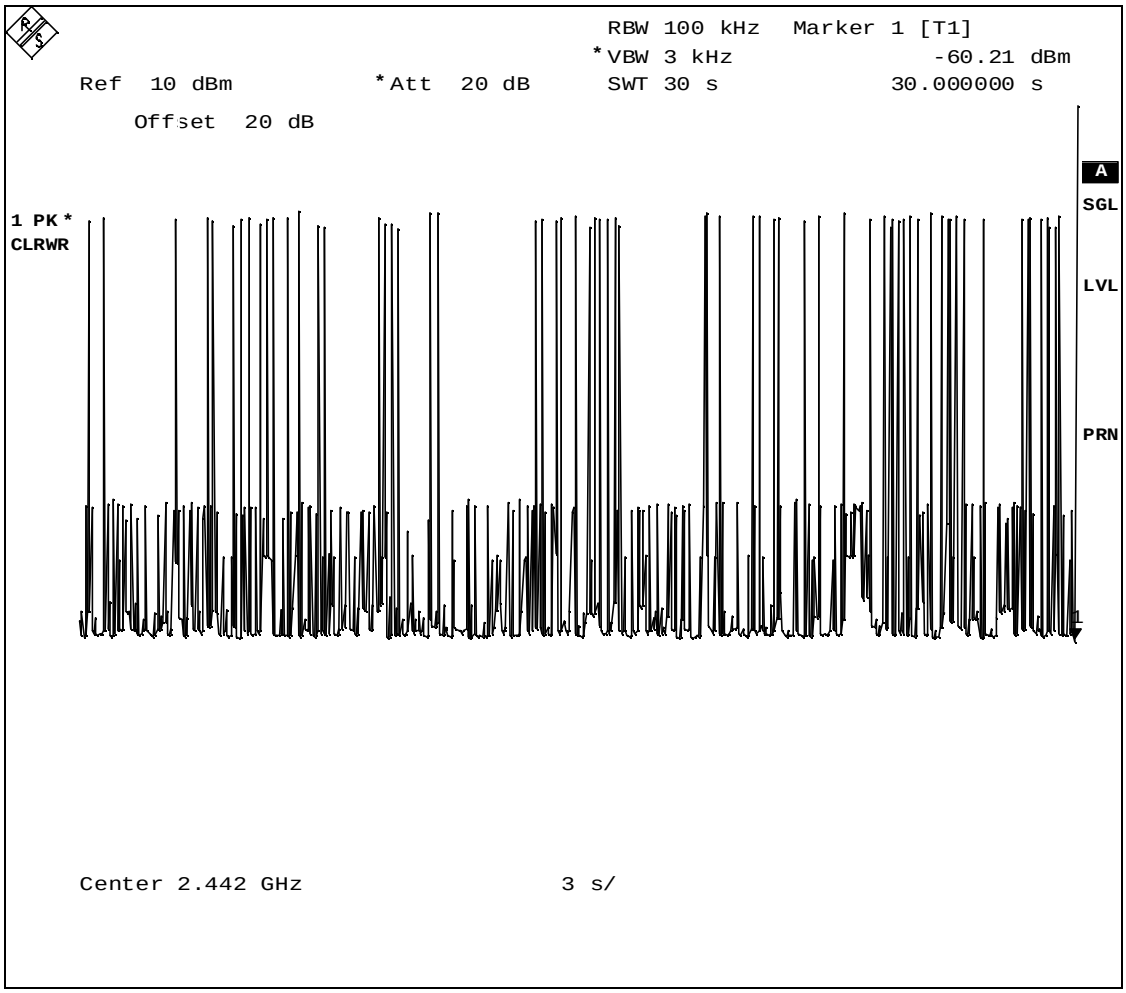

Figure 6-Channel occupancy in hopping mode: 30 second plot of activity on one channel in hopping Mode

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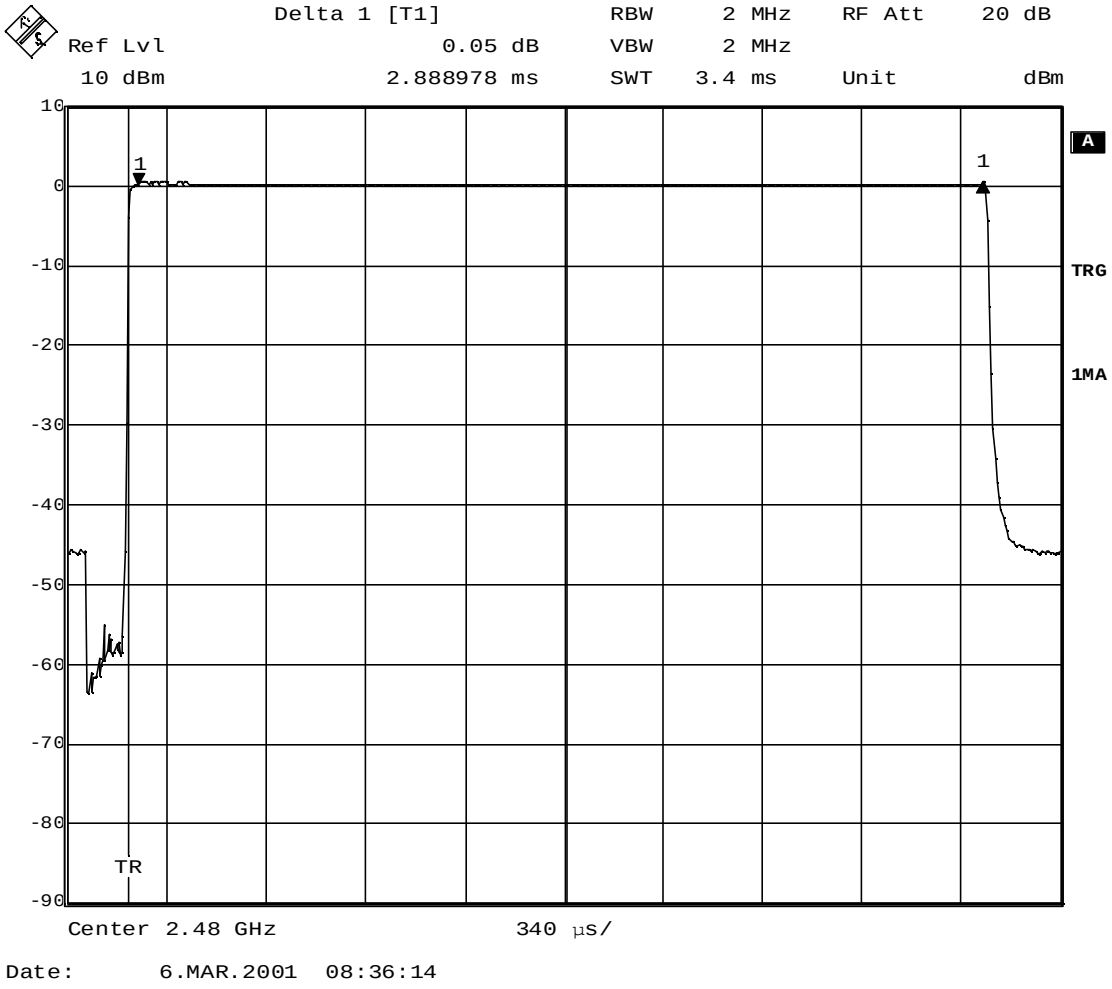

Figure 7-Channel occupancy in hopping mode: Slot length of used packet

Question 8.

Output power

See page 7 of the test report. The maximum radiated power output using 0 dBi integral antenna was 0.759 mW EIRP.

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Question 9.

EIRP limit

The antenna gain is 0 dBi. The maximum radiated output power is 0.759 mW EIRP with integral antenna.

Question 10.

RF safety requirement

RF Exposure statement can be found as Exhibit 18 of initial submission.

Question 11.

Spurious emission limits

Reference can be found in pages 21 and 22 of test report.

Question 12.

Compliance with rules for short bursts

The Bluetooth device complies with the definition of frequency hopping systems.

- 79 hopping channels
- Minimum channel separation
- Pseudorandom hopping
- Usage of frequency equally on average
- Receiver bandwidth and synchronization

Question 13.

Coordination requirement

The channel selection is represented by a pseudorandom hopping sequence hopping through 79 channels. The hopping sequence is unique for the piconet and is determined by the Bluetooth device address of the master. The Bluetooth clock of the master determines the phase in the hopping sequence. The channel is divided into time slots where each slot corresponds to a RF hop frequency. The nominal hop rate is 1600 hops/s. This leads to an individual hopping sequence for a Bluetooth piconet.

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Information with regard to the Bluetooth device operates in the page and inquiry mode under the Spread spectrum Hybrid requirements.

Question 14.

Processing gain requirement

In both page and inquiry mode, there is only one bit of information, namely the absence or presence of correct access code for a given system unit. Since the access codes used in page and inquiry consist of 68 bits, this can be viewed as if one bit of information was transmitted by means of direct-sequence operation with the spreading function defined by the access code. This viewpoint, namely that Bluetooth can be regarded as a hybrid system when inquiry or page mode with the access code defined as spreading function with 68 bits recognized as one bit of information has been shared by SIG and accepted by FCC.

Further details can be found in the processing gain report for the Bluetooth device, which has been submitted as Exhibit 1 of the initial submission. The Nokia document reference number is DTX01322-EN.

Question 15.

Average time of channel occupancy requirement for hybrid systems

Page mode

In page mode an individual transmission on a channel is 136 microseconds long. During a 12.8 second time period, the dwell time on a given channel is 87 microseconds long.

There are 5 blocks of 1.28 sec in the first plot (figure 8). The next plot (figure 9) shows, that there's a transmission every 10 msec. That means that in the time of 12.8 sec there are 5 (blocks) multiplied with 128 (transmissions per block) = 640 transmissions. Every transmission lasts 136 µsec as shown in the last plot (figure 10). So the active time on a channel is 640 (transmissions) multiplied with 116 µs = 87 msec. This is well within the requirement of maximal 400 msec.

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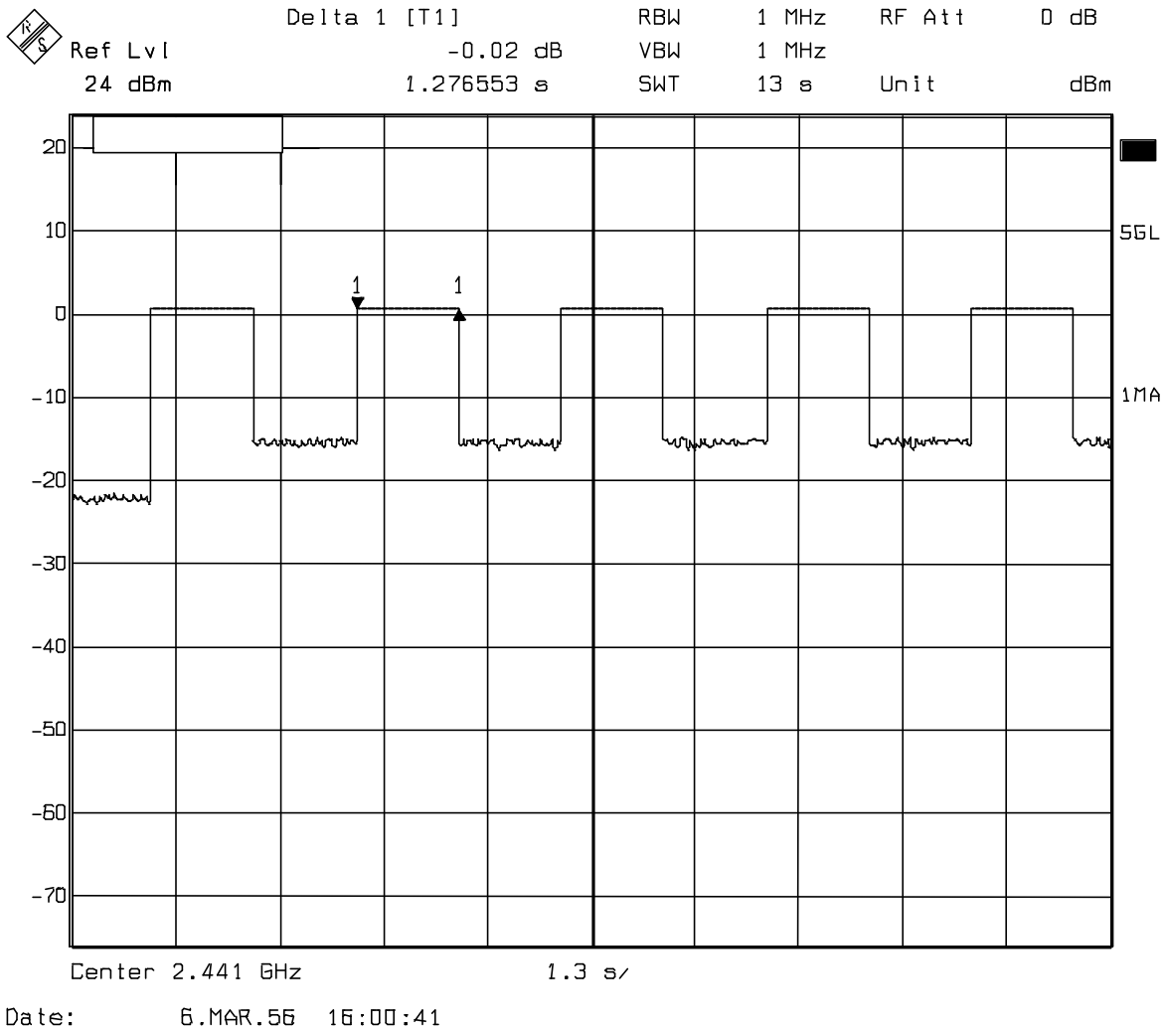

Figure 8-Channel occupancy in hybrid mode: 13 second plot of activity on one channel in page mode

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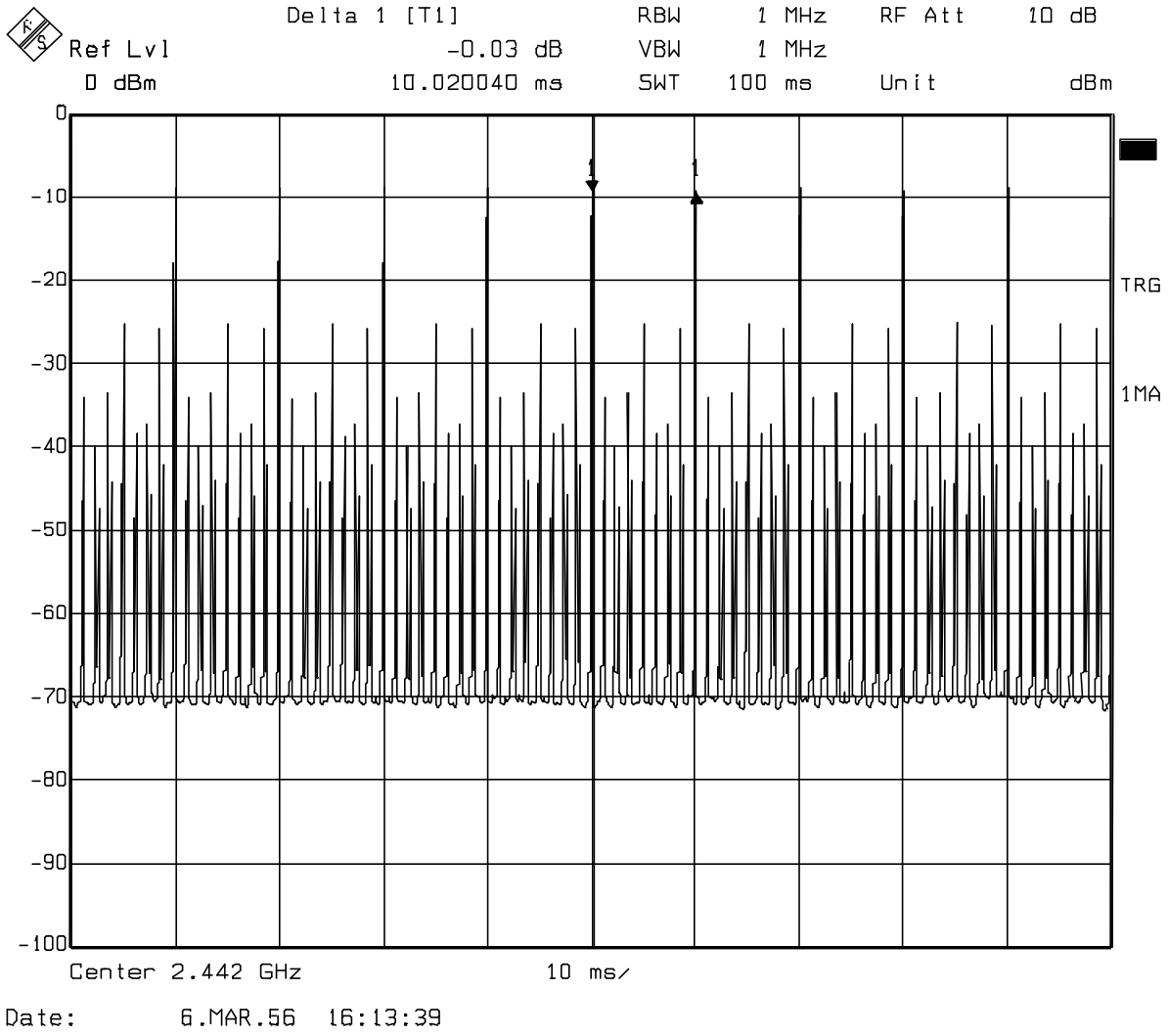

Figure 9- Channel occupancy in hybrid mode: 100 millisecond plot of activity on one channel in page Mode

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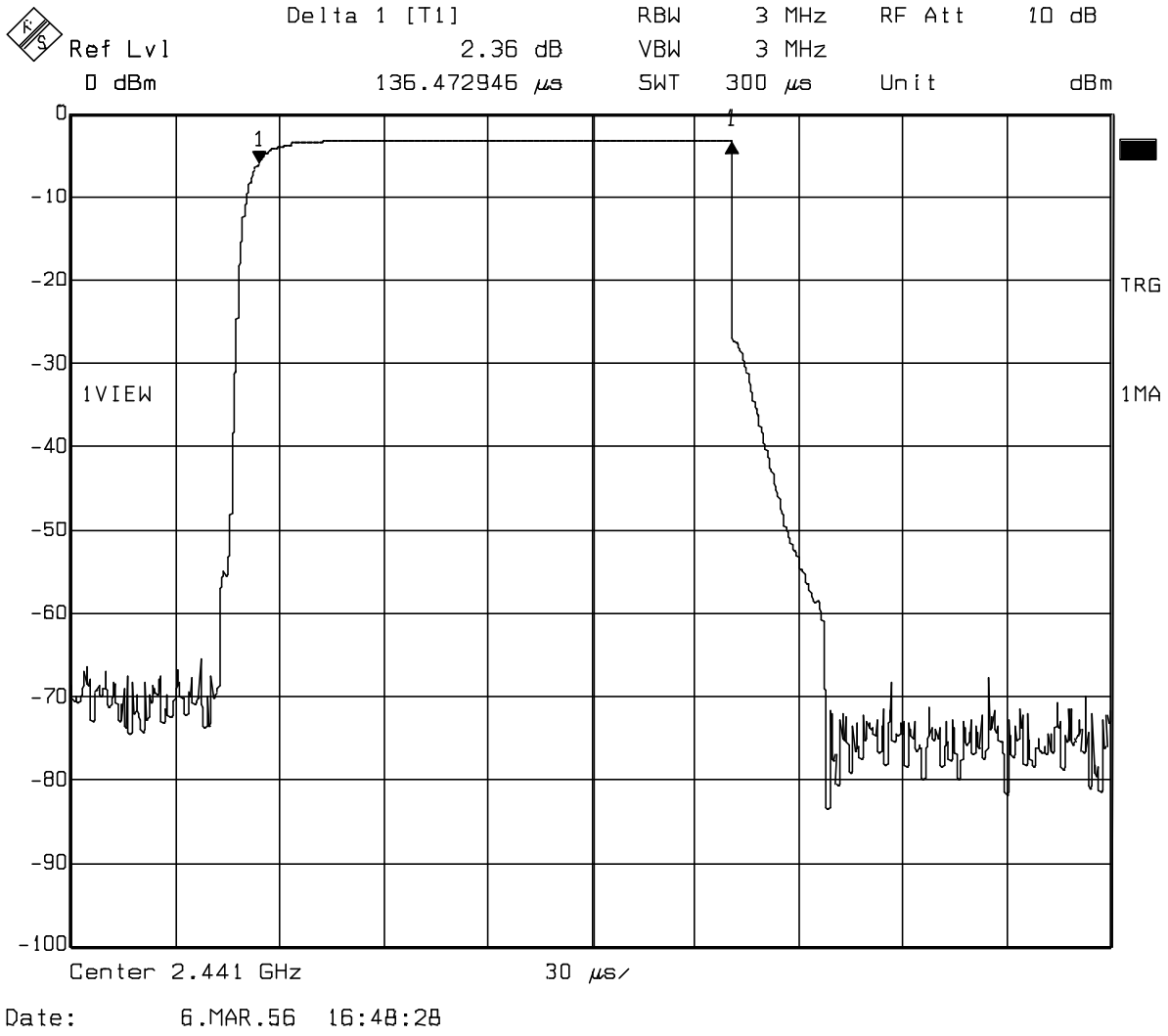

Figure 10- Channel occupancy in hybrid mode: 300 microsecond plot of activity on one channel in page Mode

Inquiry mode

In inquiry mode an individual transmission on a channel is 133.5 microseconds long. During a 12.8 second time period, the dwell time on a given channel is 68.3 microseconds long.

There are 2 blocks of 2.56 sec in the first plot (figure 11). The next plot (figure 12) shows, that there's a transmission every 10 msec. That means that in the time of 12.8 sec there are 2 (blocks) multiplied with 256 (transmissions per block) = 512 transmissions. Every transmission lasts 133.5 µsec as shown in the last plot (figure 13). So the active time on a channel is 512 (transmissions) multiplied with 133.5 µs = 68.3 msec. This is well within the requirement of maximal 400 msec.

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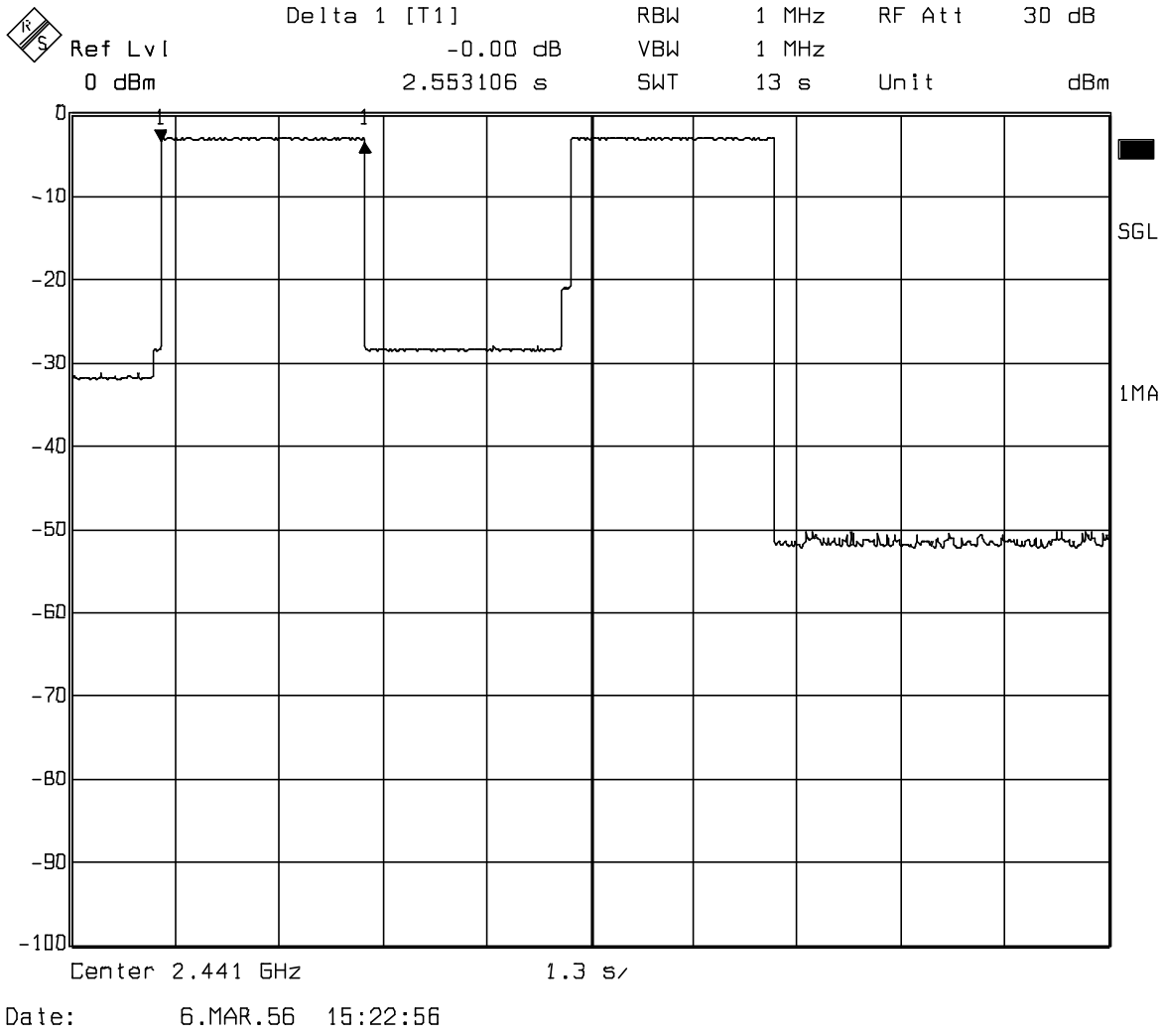

Figure 11-Channel occupancy in hybrid mode: 13 second plot of activity on one channel in inquiry mode

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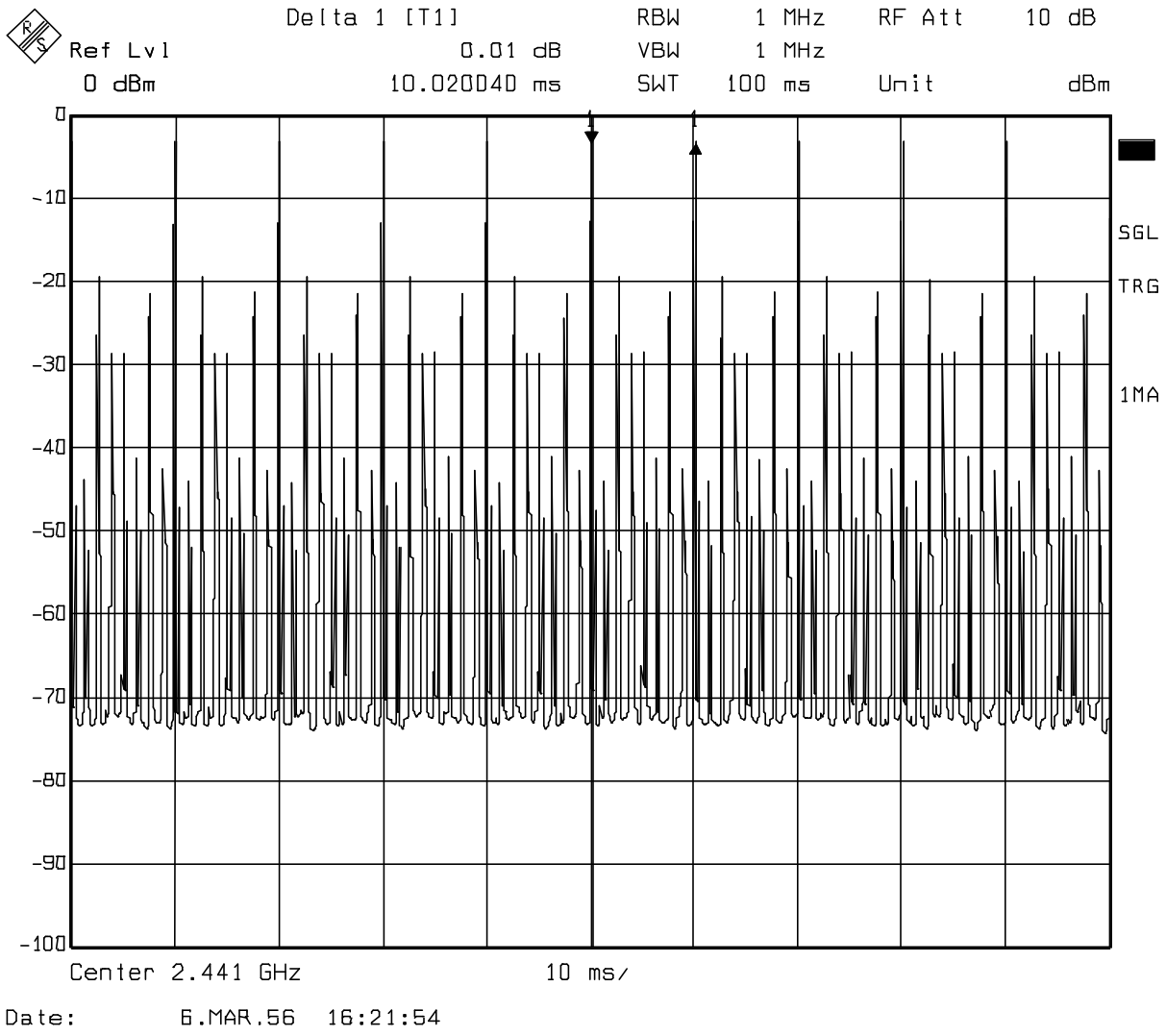

Figure 12- Channel occupancy in hybrid mode: 100 millisecond plot of activity on one channel in inquiry Mode

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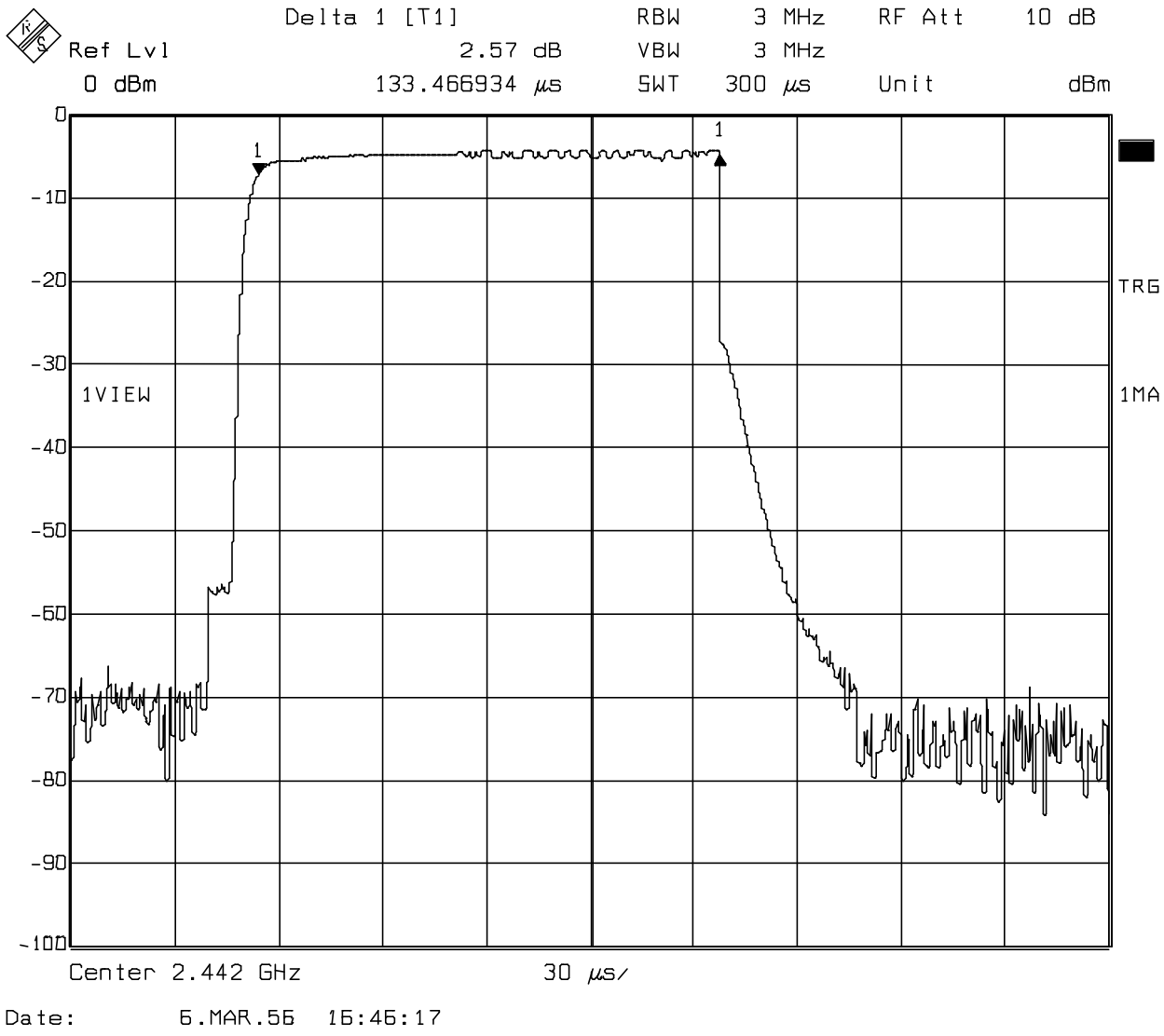

Figure 13- Channel occupancy in hybrid mode: 300 microsecond plot of activity on one channel in inquiry mode

Question 16.

Power spectral density limit

The power density is listed on page 29, 30, 36, 37 and 43 of the test report.

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Question 17.

Minimum channel separation requirement

The channel spacing of the device is 2 MHz in hybrid mode. Following plots of a spectrum analyzer show the separation between peaks and adjacent channels.

Page mode

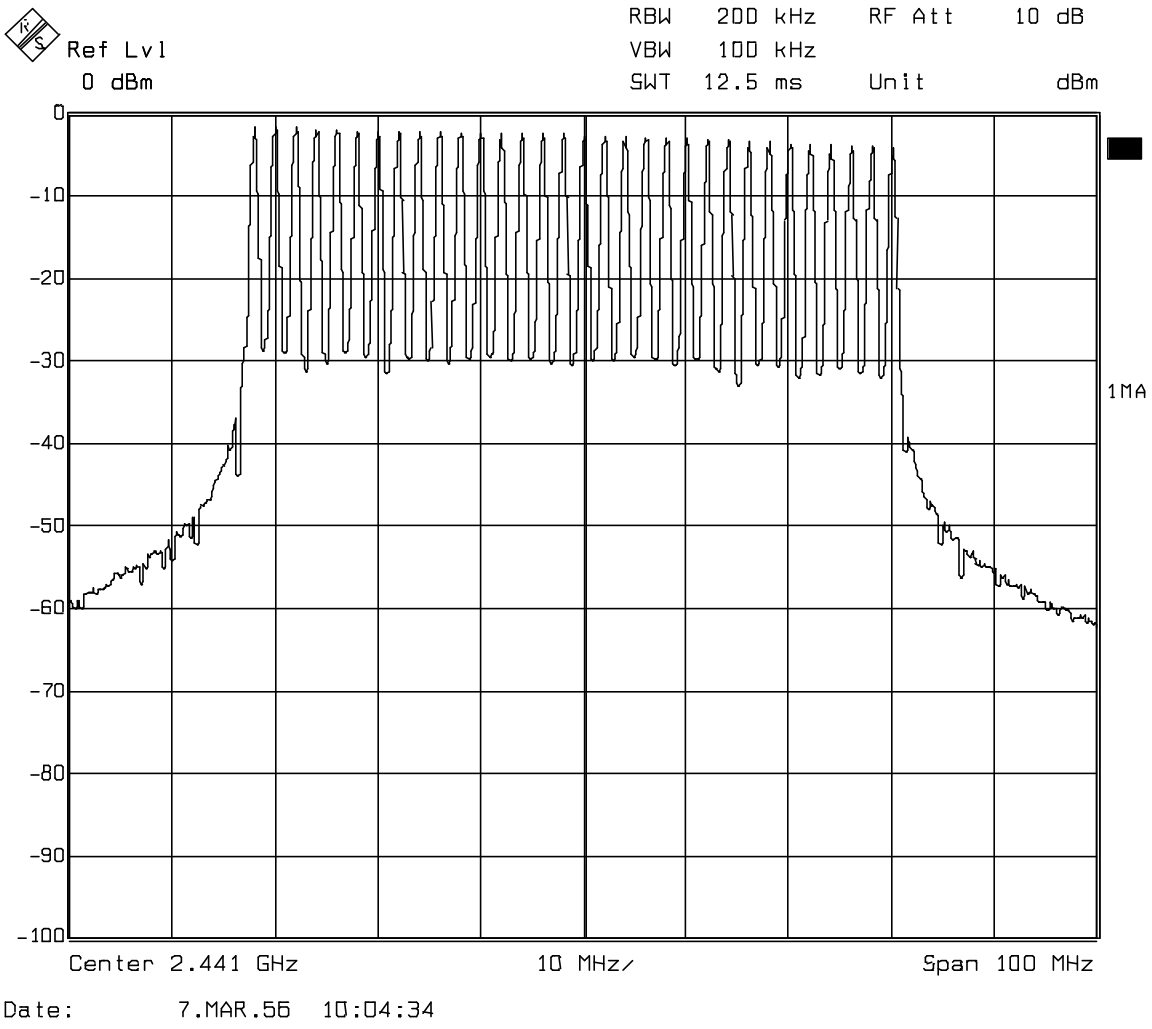

Figure 14- Complete Sequence: This figure shows the limited channel numbers in page mode. 32 channels with 2MHz channel separation can be seen.

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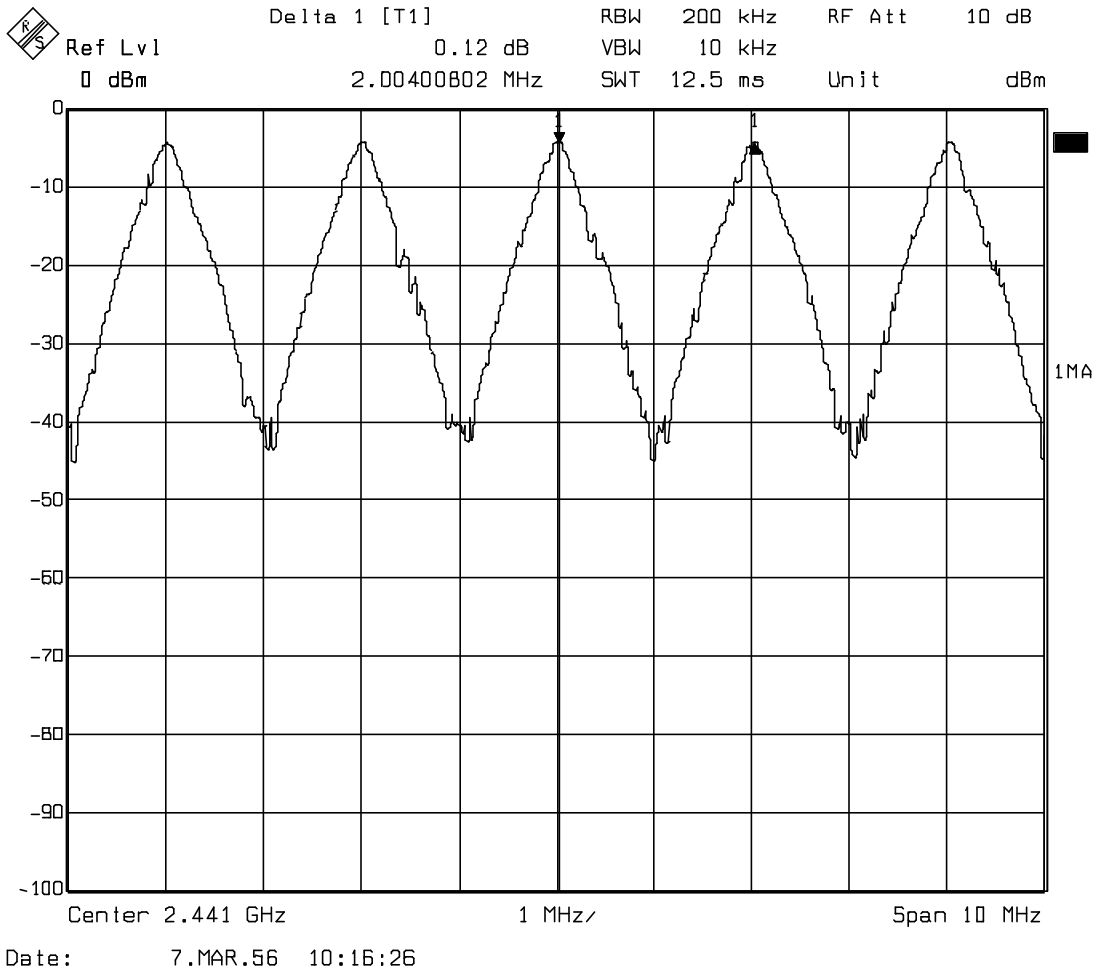

Figure 15 -Channel Spacing: This sweep was made over a span of 10 MHz to show more detail. Here from the 2 MHz channel spacing can be derived.

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Inquiry mode

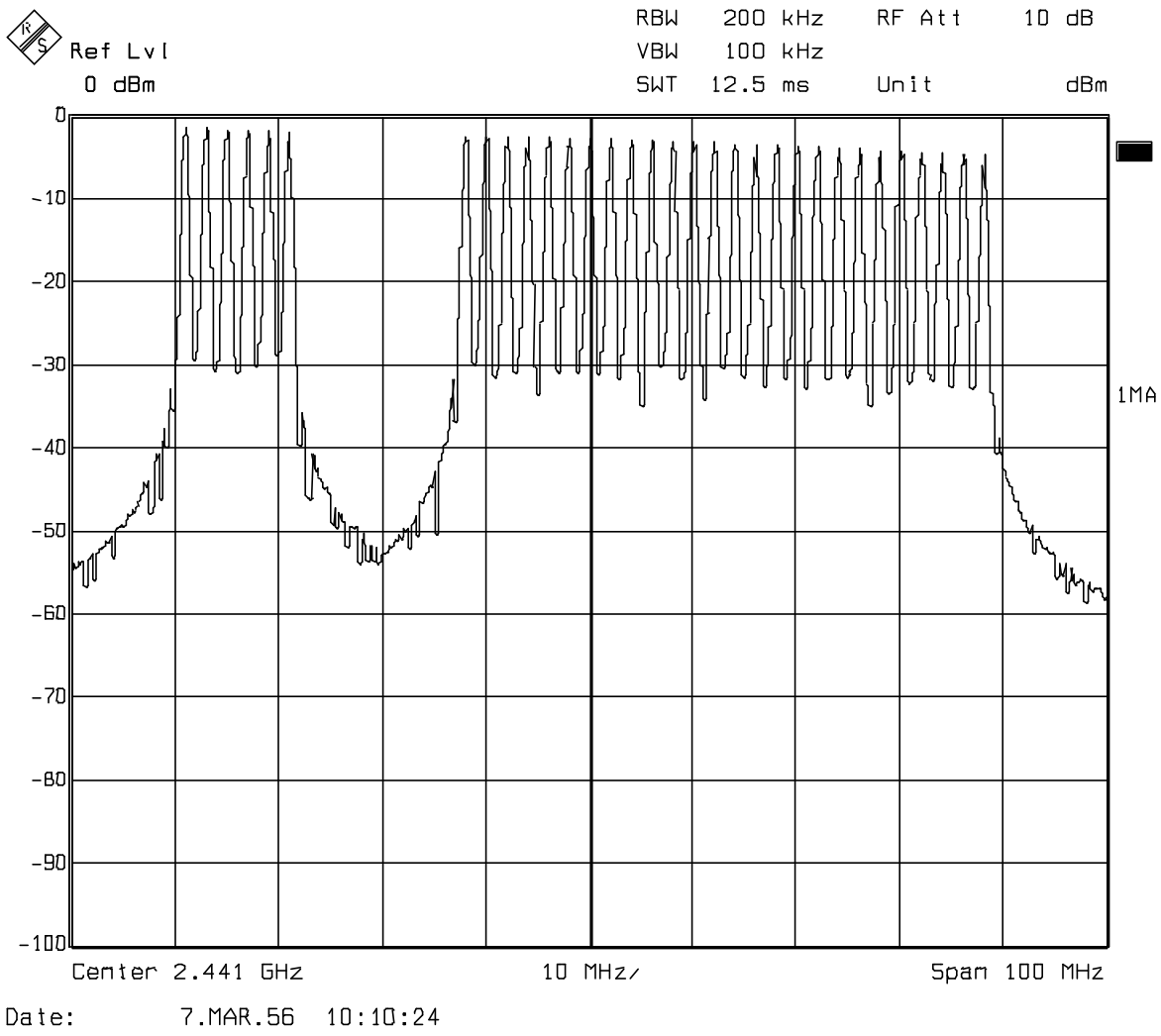

Figure 16- Complete Sequence: This figure shows the limited channel numbers in inquiry mode. 32 channels with 2 MHz channel separation can be seen.

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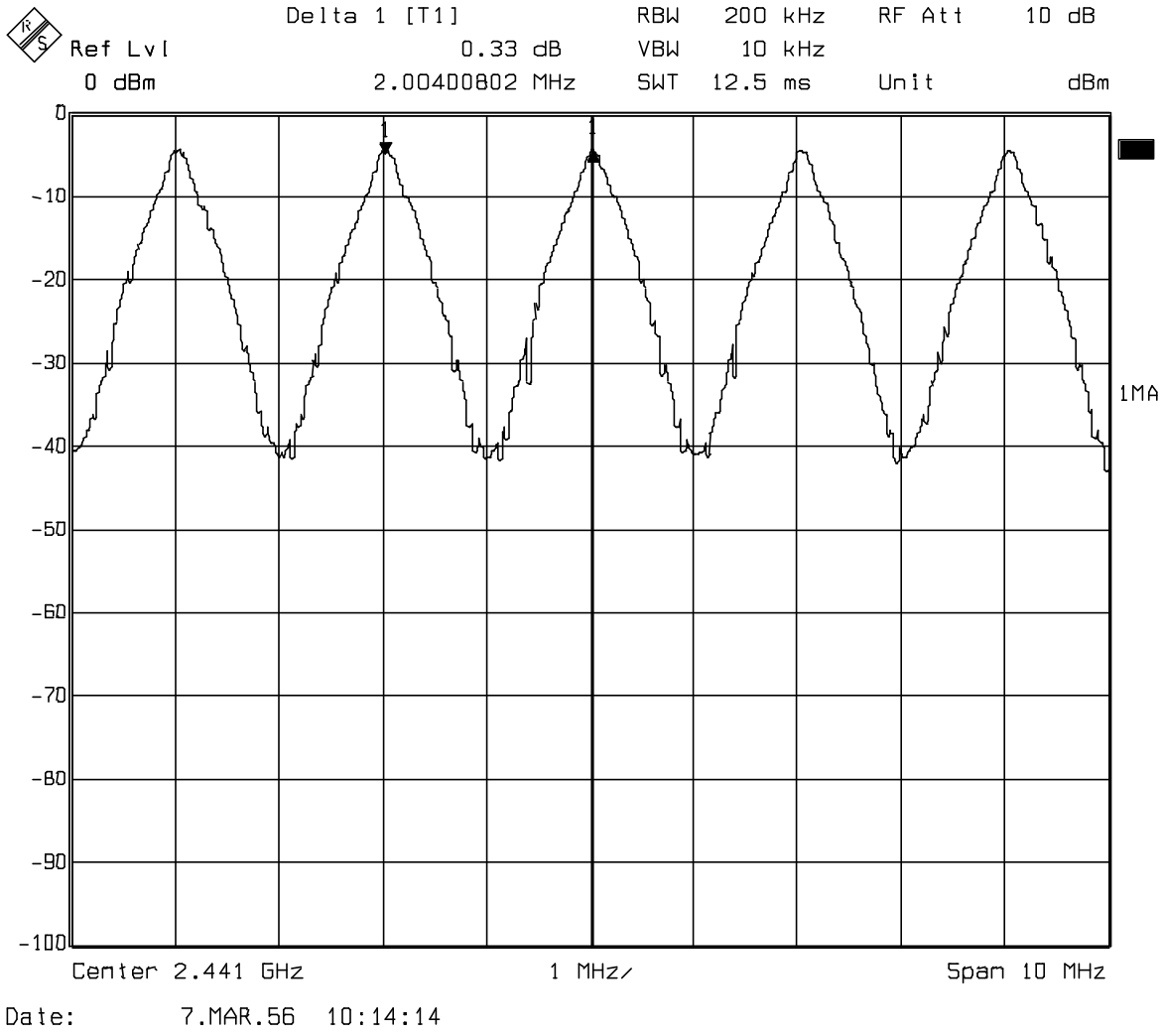

Figure 17 -Channel Spacing: This sweep was made over a span of 10 MHz to show more detail. Here from the 2 MHz channel spacing can be derived.

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Question 18.

Pseudorandom hop sequence

The pseudorandom sequence is generated in a nine-stage shift register whose 5th and 9th stage outputs are added in a module-two addition stage with the result fed back to input of the first stage. This produces a pseudorandom sequence length of 31 bits for page and inquiry modes and provides for transition to a 511 bit pseudorandom sequence length for data mode of operation.

The following are two examples of possible hopping schemes for inquiry and Page State.

Sequence example c:

48, 50, 09, 13, 52, 54, 41, 45, 56, 58, 11, 15, 60, 62, 43, 47,

00, 02, 64, 68, 04, 06, 17, 21, 08, 10, 66, 70, 12, 14, 19, 23

Sequence example d:

41, 05, 10, 04, 09, 43, 06, 16, 47, 11, 18, 12, 15, 45, 14, 32,

49, 13, 34, 28, 17, 51, 30, 24, 55, 19, 26, 20, 23, 53, 22, 40

Question 19.

Use of each frequency equally on average

A sending unit transmits the FHS (frequency hopping selection) packet. It contains UAP (upper address part) / LAP (lower address part) as well as clock information which is updated before retransmission in the inquiry state. When in hybrid substate, the UAP/LAP is used together with the clock to select the sequence. The output from the selection box constitutes a pseudorandom sequence covering 79 hops.

For inquiry mode, the selection scheme chooses a segment of 32 hop frequencies from the 79 hops spanning about 64 MHz and visits these hops once in a random order. Next, a different 32-hop segment is chosen, etc. .

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Question 20.

Receiver matching bandwidth and synchronization

Receiver bandwidth

The receiver bandwidth in hybrid mode (32 channels) is equal to the receiver bandwidth in the 79 channel hopping mode, which is 1 MHz.

Synchronization

Synchronization within a piconet uses a system of beacon channels generated by the master unit with the remaining slave units periodically waking up and listening on a beacon channel. Beacon channels are designated by the master unit in page mode to identify channels for slave units to listen to. The beacon channel packet also contains the synchronization information required for the slave to synchronize with the master unit.

In page mode the same 32-hop segment is used all the time and the segment is selected by the address with different units having different paging segments. Although they are referred to as beacon channels, they are designated as beacons only for purpose of assisting the listening function for establishing a connection. The master unit is continually hopping through all 32 channels in the page mode. When two Bluetooth devices establish contact for the first time, one of the devices is sending out an inquiry access code, and the other party is scanning for this inquiry access code.

If the two devices have been connected previously, and want to start a new session, a similar procedure takes place. The only difference being that instead of the inquiry access code, an access code derived from the page unit's address is used. If the two Bluetooth devices have exchanged information during the last five hours, the typical time it takes to establish the connection is reduced considerably due to the ability of the paging unit to estimate at what frequency the other unit will perform the page scan.

Question 21.

Conducted output power

The conducted output power of the Bluetooth device in hybrid mode is 1.26 mW.

Question 22.

Spurious emission limits

Reference can be found in pages 13,17 and 21 of the test report.

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