EBU – TECH 3306-2007

RF64: An extended File Format for Audio

A BWF-compatible multichannel file format enabling file sizes to exceed 4 Gbyte

Status: Technical Specification

Geneva
February 2007

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RF64: An Extended File Format for Audio

EBU Committee	*First Issued*	*Revised*	*Re-issued*
PMC	2006	December 2006	2007

Keywords: RF64, BWF, MBWF, Multichannel Audio, Files

1. INTRODUCTION

The RF64 file format should fulfil the longer-term need for multichannel sound in broadcasting and archiving. The required effort for software implementers is very small. The changes that will be needed to update existing systems will be reasonable in cost.

An RF64 file has additions to the basic *Microsoft RIFF/WAVE* specification to allow for either, or both:

- more than 4 Gbyte file sizes when needed
- A maximum of 18 surround channels, stereo downmix channel and bitstream signals with non-PCM coded data. This specification is based on the *Microsoft Wave Format Extensible [1]* for multichannel parameters.

The file format is designed to be a compatible extension to the Microsoft *RIFF/WAVE* format and to the *BWF [2] [3]* and its supplements and additional chunks. It extends the maximum size capabilities of the *RIFF/WAVE* and BWF thus allowing for multichannel sound in broadcasting and audio archiving.

RF64 can be used in the entire programme chain from capture to editing and play out and for short or long term archiving of multichannel files.

An RF64 file with a bext chunk becomes an MBWF (Multichannel BWF) file. The terms ‘RF64’ and ‘MBWF’ can then be considered synonymous.

2. BASIC USER REQUIREMENTS

The basic user requirements were derived from discussions with a group of EBU Members. They are summarised below:

- The file format should have an open, published specification
- Backwards compatibility to BWF and RIFF/WAVE must be maintained
- Linear PCM must be accommodated
- File sizes more than 4 Gbyte must be accommodated
- Minimum 8 channels (5.1 + stereo) must be accommodated
- Simulcast (5.1 + stereo in a single file) should be possible
- Streaming should be possible
- Editing should be possible

- A browsing version should be derivable directly from the file
- Must contain the technical Metadata necessary for play-back (e.g. Dolby Metadata)
- A low cost, easily accessible software player should be available
- Easy implementation for software developers and manufacturers.

Additionally, Swedish operational experience has demonstrated that production and archiving often require storing and transport of PCM and non-PCM audio data, both or either in a single file. Consequently, mechanisms for accommodating non-PCM audio streams (e.g. Dolby Digital and DTS) have been added to the RF64 format.

3. DEFINITION OF A NEW FORMAT, RF64

With the advent of Windows 2000 Microsoft introduced the multichannel extension to its RIFF/WAVE file format, called *Wave Format Extensible*. The main purpose of this file format was to support multichannel audio in PC gaming applications.

The Wave Format Extensible channel mask contains 18 "#define" settings specifying different loudspeaker positions (or channel allocations). Another "#define", "SPEAKER_ALL" turns on all loudspeakers (channels).

Microsoft Wave Format Extensible Channel Mask

#define SPEAKER_FRONT_LEFT	0x00000001
#define SPEAKER_FRONT_RIGHT	0x00000002
#define SPEAKER_FRONT_CENTER	0x00000004
#define SPEAKER_LOW_FREQUENCY	0x00000008
#define SPEAKER_BACK_LEFT	0x00000010
#define SPEAKER_BACK_RIGHT	0x00000020
#define SPEAKER_FRONT_LEFT_OF_CENTER	0x00000040
#define SPEAKER_FRONT_RIGHT_OF_CENTER	0x00000080
#define SPEAKER_BACK_CENTER	0x00000100
#define SPEAKER_SIDE_LEFT	0x00000200
#define SPEAKER_SIDE_RIGHT	0x00000400
#define SPEAKER_TOP_CENTER	0x00000800
#define SPEAKER_TOP_FRONT_LEFT	0x00001000
#define SPEAKER_TOP_FRONT_CENTER	0x00002000
#define SPEAKER_TOP_FRONT_RIGHT	0x00004000
#define SPEAKER_TOP_BACK_LEFT	0x00008000
#define SPEAKER_TOP_BACK_CENTER	0x00010000
#define SPEAKER_TOP_BACK_RIGHT	0x00020000
#define SPEAKER_ALL	0x80000000

To fulfil the user requirements listed above, RF64 requires some enhancements to the basic *Wave Format Extensible* channel mask. Fortunately this is stored in a 32-bit variable that can therefore accommodate a further 13 "#defines" to allow this increased functionality.

3.1 Enhancement for a PCM stereo down mix

No PCM stereo signal is included in the basic *Wave Format Extensible*.

To include a stereo channel the following is added:

```
#define SPEAKER_STEREO_LEFT              0x20000000
#define SPEAKER_STEREO_RIGHT             0x40000000
```

With this enhancement a multichannel 'X.1' and a stereo down mix can be accommodated in a single file.

3.2 Enhancement for control data

Addition of two new "#define" values for control data:

```
#define SPEAKER_CONTROLSAMPLE_1          0x08000000
#define SPEAKER_CONTROLSAMPLE_2          0x10000000
```

These control samples can be stored within the file. Technical or content metadata can be positioned with sample accuracy along the essence file time line. The details of this feature are yet to be defined.

3.3 Enhancement for bitstream non-PCM data

Bitstream signals according to IEC *[4]* and SMPTE *[5]* standards carry non-PCM multichannel audio data coded with various perceptual methods.

Through this bitstream storage feature in the file format, Dolby AC3, Dolby E, DTS, MPEG-1 and 2 (at all three layers) and MPEG-2 AAC will be contained in the file as data bursts, "disguised" as PCM linear. The bitstream audio signal is embedded in a structure that is similar to two interleaved stereo audio channels in a linear PCM RIFF/WAVE or BWF file.

In RIFF files there is only one format chunk defining common parameters for all interleaved channels in the audio data chunk. The format of the bitstream channels must comply with the format of other multichannel PCM or stereo PCM channels if they are present in the same file.

To a receiver of the file, the type of non-PCM audio coding will be known only when the bitstream is decoded from AES3 or SPDIF. It is likely that a new chunk will be developed to signal the bitstream format contained in the file.

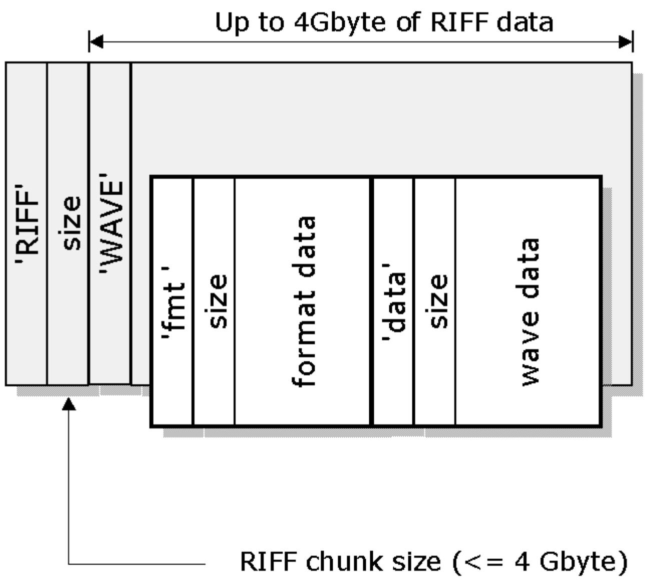
Adding 4 more "#define" values to the *Wave Format Extensible* channel mask will allow two different non-PCM formats, as follows:

```
#define SPEAKER_BITSTREAM_1_LEFT         0x00800000
#define SPEAKER_BITSTREAM_1_RIGHT        0x01000000
#define SPEAKER_BITSTREAM_2_LEFT         0x02000000
#define SPEAKER_BITSTREAM_2_RIGHT        0x04000000
```

3.4 Breaking the 4 gigabyte barrier

The reason for the 4 Gbyte barrier is the 32-bit addressing in RIFF/WAVE and BWF. With 32 bits a maximum of 4294967296 bytes = 4 Gbyte can be addressed. To solve this issue, 64-bit addressing is needed.

Standard RIFF/WAVE format



Note: All fields except "format data" and "wave data" are 32-bit fields

Just changing the size of every field in a BWF to 64-bit would produce a file that is not compatible with the standard RIFF/WAVE format - an obvious but important observation.

The approach adopted is to define a new 64-bit based Resource Interchange File Format called RF64 that is identical to the original RIFF/WAVE format, except for the following changes:

- The ID 'RF64' is used instead of 'RIFF' in the first four bytes of the file
- A mandatory 'ds64' (data size 64) chunk is added, which has to be the first chunk after the "RF64 chunk".

  The 'ds64' chunk has three mandatory 64-bit integer values, which replace three 32-bit fields of the RIFF/WAVE format:

  - riffSize (replaces the RIFF size field)
  - dataSize (replaces the size field of the 'data' chunk)
  - sampleCount (replaces the sample count value in the 'fact' chunk)

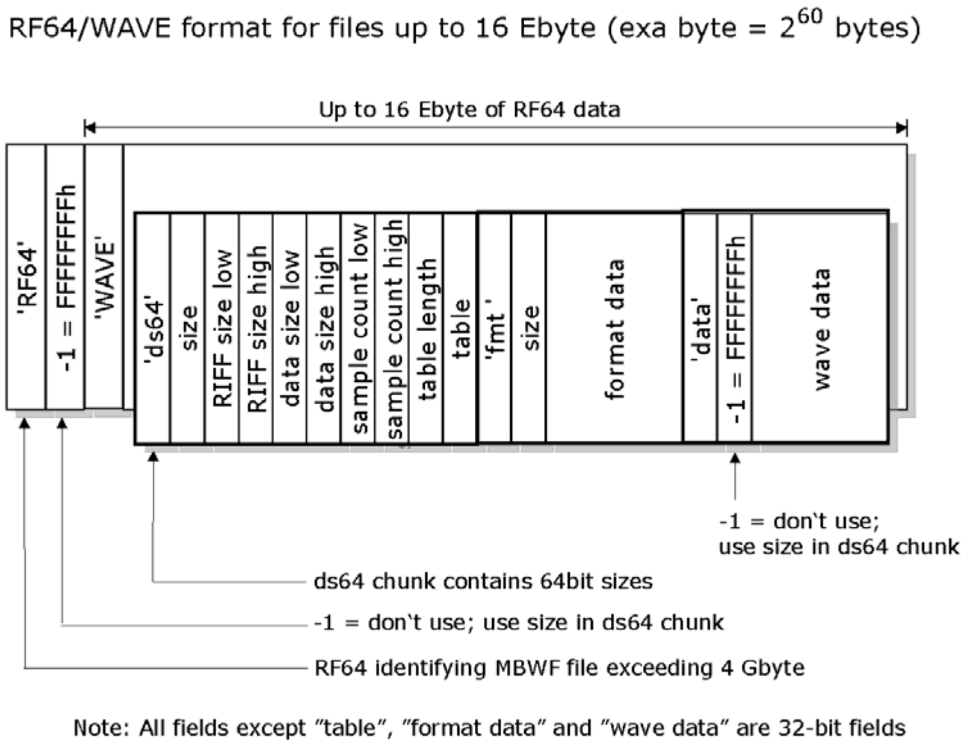
For all three 32-bit fields of the RIFF/WAVE format the following rule applies:

If the 32-bit value in the field is not "-1" (= FFFFFFFF hex) then this 32-bit value is used. If the 32-bit value in the field is "-1" the 64-bit value in the 'ds64' chunk is used instead.

- One optional array of structs[2] (see Annex A) with additional 64-bit chunk sizes is possible

The complete structure of the RF64 file format is illustrated in the following figure:

[2] "Struct" is a C/C++ keyword that defines a structure type and/or a variable of a structure type.


RF64/WAVE format for files up to 16 Ebyte (exa byte = 2^60 bytes)
Up to 16 Ebyte of RF64 data
'RF64'
-1 = FFFFFFFFh
'WAVE'
'ds64'
size
RIFF size low
RIFF size high
data size low
data size high
sample count low
sample count high
table length
table
'fmt '
size
format data
'data'
-1 = FFFFFFFFh
wave data
-1 = don't use; use size in ds64 chunk
ds64 chunk contains 64bit sizes
-1 = don't use; use size in ds64 chunk
RF64 identifying MBWF file exceeding 4 Gbyte
Note: All fields except "table", "format data" and "wave data" are 32-bit fields

3.5 Achieving compatibility between BWF and RF64

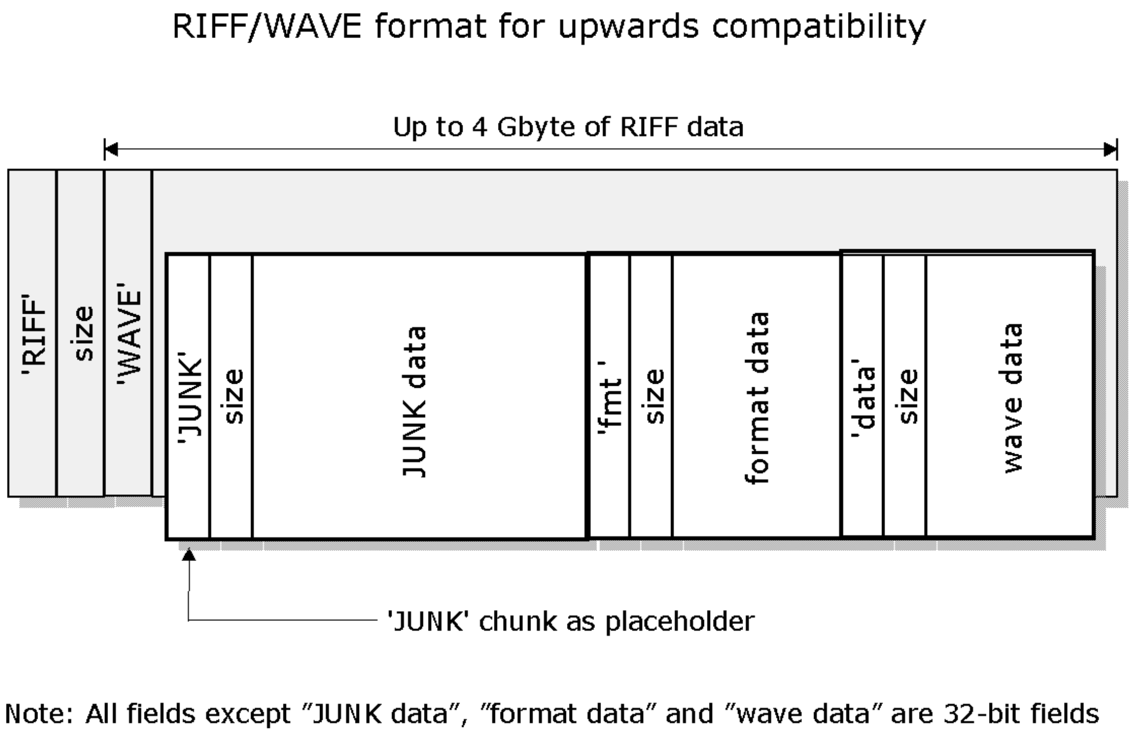
In spite of higher sampling frequencies and multi-channel audio, some production audio files will inevitably be smaller than 4 Gbyte and they should therefore stay in Broadcast Wave Format.

The problem arises that a recording application cannot know in advance whether the recorded audio it is compiling will exceed 4 Gbyte or not at end of recording (i.e. whether it needs to use RF64 or not).

The solution is to enable the recording application to switch from BWF to RF64 on the fly at the 4 Gbyte size-limit, while the recording is still going on.

This is achieved by reserving additional space in the BWF by inserting a 'JUNK' chunk [3] that is of the same size as a 'ds64' chunk. This reserved space has no meaning for Broadcast Wave, but will become the 'ds64' chunk, if a transition to RF64 is necessary.

[3] The 'JUNK' chunk is part of the original RIFF/WAVE standard. It is a placeholder and it will be ignored by any audio application.


RIFF/WAVE format for upwards compatibility
Up to 4 Gbyte of RIFF data
'RIFF'
size
'WAVE'
'JUNK'
size
JUNK data
'fmt '
size
format data
'data'
size
wave data
'JUNK' chunk as placeholder
Note: All fields except "JUNK data", "format data" and "wave data" are 32-bit fields

At the beginning of a recording, a RF64-aware application will create a standard RIFF/WAVE or BWF with a 'JUNK' chunk as the first chunk. While recording, it will check the RIFF and data sizes. If they exceed 4 Gbyte, the application will:

- Replace the chunkID 'JUNK' with 'ds64' chunk. (this transforms the previous JUNK chunk into a ds64 chunk).
- Insert the RIFF size, 'data' chunk size and sample count in the 'ds64' chunk
- Set RIFF size, 'data' chunk size and sample count in the 32 bit fields to -1 = FFFFFFFF hex
- Replaces the ID 'RIFF' with 'RF64' in the first four bytes of the file
- Continue with the recording.

Annex A: Formal description of RIFF/WAVE and RF64/WAVE structures

A.1 Chunks and Structs in the RIFF/WAVE (BWF) format

```
struct RiffChunk                                    // declare RiffChunk structure
{
        char                chunkId[4];             // 'RIFF'
        unsigned int32      chunkSize;              // 4 byte size of the traditional RIFF/WAVE file
        char                riffType[4];            // 'WAVE'
};

struct JunkChunk                                    // declare JunkChunk structure
{
        char                chunkId[4];             // 'JUNK'
        unsigned int32      chunkSize;              // 4 byte size of the 'JUNK' chunk. This must be at
                                                    // least 28 if the chunk is intended as a
                                                    // place-holder for a 'ds64' chunk.
        char                chunkData[ ][4];        // dummy bytes
};

struct FormatChunk[5]                               // declare FormatChunk structure
{
        char                chunkId[4];             // 'fmt '
        unsigned int32      chunkSize;              // 4 byte size of the 'fmt ' chunk
        unsigned int16      formatType;             // WAVE_FORMAT_PCM = 0x0001, etc.
        unsigned int16      channelCount;           // 1 = mono, 2 = stereo, etc.
        unsigned int32      sampleRate;             // 32000, 44100, 48000, etc.
        unsigned int32      bytesPerSecond;         // only important for compressed formats
        unsigned int16      blockAlignment;         // container size (in bytes) of one set of samples
        unsigned int16      bitsPerSample;          // valid bits per sample 16, 20 or 24
        unsigned int16      cbSize                  // extra information (after cbSize) to store
        char                extraData[22]           // extra data of WAVE_FORMAT_EXTENSIBLE when necessary
};

struct DataChunk                                    // declare DataChunk structure
{
        char                chunkId[4];             // 'data'
        unsigned int32      chunkSize;              // 4 byte size of the 'data' chunk
        char                waveData[ ]             // audio samples
};
```

Note: Any other chunks that are valid in a RIFF/WAVE file are also valid in a RF64/WAVE file. For example, the BWF extensions for RIFF/WAVE can be used "as is" in any RF64/WAVE file.

[4] The empty bracket is not standard C/C++ syntax. It is used to show that these arrays have a variable number of elements (which might even be zero).

[5] This is already the specialised format chunk for PCM audio data.

A.2 New Chunks and Structs in the RF64/WAVE (MBWF) format

```
struct RF64Chunk                              // declare RF64Chunk structure
{
        char            chunkId[4];           // 'RF64'
        unsigned int32  chunkSize;            // -1 = 0xFFFFFFFF means don't use this data, use
                                              // riffSizeHigh and riffSizeLow in 'ds64' chunk instead
        char            rf64Type[4];          // 'WAVE'
};

struct ChunkSize64                            // declare ChunkSize64 structure
{
        char            chunkId[4];           // chunk ID (i.e. "big1" – this chunk is a big one)
        unsigned int32  chunkSizeLow;         // low 4 byte chunk size
        unsigned int32  chunkSizeHigh;        // high 4 byte chunk size
};

struct DataSize64Chunk                        // declare DataSize64Chunk structure
{
        char            chunkId[4];           // 'ds64'
        unsigned int32  chunkSize;            // 4 byte size of the 'ds64' chunk
        unsigned int32  riffSizeLow;          // low 4 byte size of RF64 block
        unsigned int32  riffSizeHigh;         // high 4 byte size of RF64 block
        unsigned int32  dataSizeLow;          // low 4 byte size of data chunk
        unsigned int32  dataSizeHigh;         // high 4 byte size of data chunk
        unsigned int32  sampleCountLow;       // low 4 byte sample count of fact chunk
        unsigned int32  sampleCountHigh;      // high 4 byte sample count of fact chunk
        unsigned int32  tableLength;          // number of valid entries in array "table"
        chunkSize64     table[ ];
};
```

The array of "ChunkSize64" structs is used to store the length of any chunk other than 'data' in the optional part of the 'ds64' chunk. Currently, no standard chunk type other than 'data' is likely to exceed a size of 4 Gbyte even in extremely large audio files (e.g. the BWF 'levl' chunk will typically exceed 4 Gbyte only when the 'data' chunk reaches about 512 Gbyte).

```
struct Guid
{
        unsigned int32      data1;
        unsigned int16      data2;
        unsigned int16      data3;
        unsigned int32      data4;
        unsigned int32      data5;
};
struct FormatExtensibleChunk              // declare FormatExtensibleChunk structure for
                                          // WAVE_FORMAT_EXTENSIBLE
{
        char                chunkId[4];          // 'fmt '
        unsigned int32      chunkSize;           // 4 byte size of the 'fmt ' chunk
        unsigned int16      formatType;          // WAVE_FORMAT_EXTENSIBLE = 0xFFFE
        unsigned int16      channelCount;        // 1 = mono, 2 = stereo, etc.
        unsigned int32      sampleRate;          // 32000, 44100, 48000, etc.
        unsigned int32      bytesPerSecond;      // only important for compressed formats
        unsigned int16      blockAlignment;      // container size (in bytes) of one set of samples
        unsigned int16      bitsPerSample;       // bits per sample in container size * 8, i.e. 8, 16, 24
        unsigned int16      cbSize               // extra information (after cbSize) to store
        unsigned int16      validBitsPerSample   // valid bits per sample i.e. 8, 16, 20, 24
        unsigned int32      channelMask          // channel mask for channel allocation
        Guid                subFormat            // KSDATAFORMAT_SUBTYPE_PCM
                                                 // data1 = 0x00000001
                                                 // data2 = 0x0000
                                                 // data3 = 0x0010
                                                 // data4 = 0xAA000080
                                                 // data5 = 0x719B3800
};
```

REFERENCES:

[1]	Wave Format Extensible:	Multiple Channel Audio Data and WAVE Files
[2]	EBU Tech 3285	Specification of the Broadcast Wave Format (BWF) - Version 1 - first edition
[3]	EBU Tech 3285 s 1 - 5	Supplements to the BWF specification
[4]	IEC 61937-1	Digital audio - Interface for non-linear PCM encoded audio bitstream applying IEC 60958 (AES3, SPDIF) - Part 1: General
	IEC 61937-3	Part 3: Non-linear PCM bitstreams according to the AC-3 format
	IEC 61937-5	Part 5: Non-linear PCM bitstreams according to the DTS format(s)
	IEC 61937-6	Part 6: Non-linear PCM bitstreams according to the MPEG2 AAC audio formats
[5]	SMPTE 337M-2000	Format for Non-PCM Audio and Data in an AES3 Serial Digital Audio Interface
	SMPTE 338M-2000	Format for Non-PCM Audio and Data in AES3 – Data Types (Supported data types: AC-3, MPEG-1 or MPEG-2, Layer 1, 2 or 3, SMPTE KLV data and Dolby E).
	SMPTE 339M-2000	Format for Non-PCM Audio and Data in AES3 – Generic Data Types
	SMPTE 340M	Format for Non-PCM Audio and Data in AES3 – ATSC A/52 (AC-3) Data Type

Wave Format extensible is explained at: www.microsoft.com/whdc/device/audio/multichaud.mspx

EBU standards are available for free download from: www.ebu.ch/en/technical/publications/index.php

IEC- standards can be purchased via: www.iec.ch/searchpub/cur_fut.htm

SMPTE-standards can be purchased via: www.smpte.org/smpte_store/standards/

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